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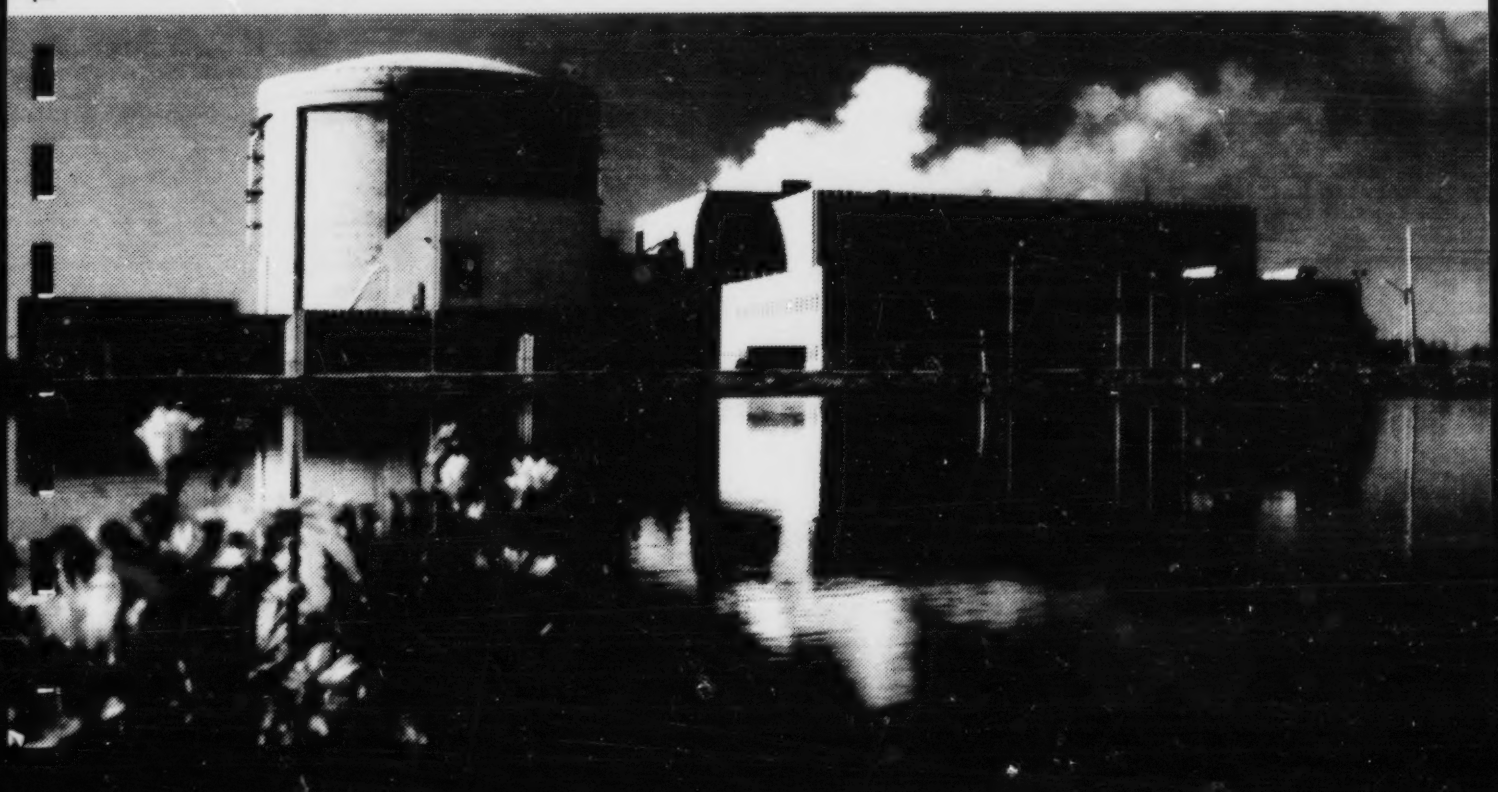
Énergie NB Power

Point Lepreau Generating Station

Environmental Radiation Monitoring Data for Point Lepreau Generating Station
January 1, 1999 to December 31, 1999



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Environmental Radiation Monitoring Data for Point Lepreau Generating Station

January 1, 1999 to December 31, 1999

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Health Physics Department
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Executive Summary

This annual report is a compilation of the 1999 results from the Environmental Radiation Monitoring Program for the Point Lepreau Generating Station (PLGS).

Since 1976, the monitoring program has analysed more than 24 000 samples to define background radiation from natural and human sources. The contribution from human sources has declined significantly since atmospheric bomb tests have ceased. The program detected radionuclide fallout in New Brunswick after a Chinese atmospheric bomb test in 1980, and fallout from the accident at Chernobyl in 1986. There have been no regionally detectable releases of radiation from any human activity since these two events.

In 1999, there were 1858 analyses on 1327 samples to monitor environmental radiation around Point Lepreau and across the province in general. The analyses indicate that radiation dose from PLGS emissions continues to be well below the public dose limit (5000 microsieverts per annum), and also well below the operating target for nuclear power facilities in Canada (50 microsieverts per annum).

The only assessable radiation dose from PLGS on the local population is that from tritiated water vapour in air. As in past years, tritium continues to be detected offsite in air and water samples. However, the only significant trends in radionuclide levels, based on an analysis of all the data from previous years are:

- increasing H-3 in Parshall Flume water from the SRWMF – Phase 1
- increasing H-3 in bore hole water from the SRWMF – Phase 1
- decreasing H-3 in onsite air samples

Source of Dose to Critical Group	*Individual Dose (μSv/a)*	*Population Dose (person-mSv/a)*
PLGS airborne emissions	0.4	1.4
PLGS liquid emissions	0.5	2.0
natural background (estimate)	2 000	320 000
medical procedures (estimate)	-------	80 000

Population-dose is the summation of all calculated doses over the entire population within a 20 km radius from PLGS for the seafood pathway, and within a 60 km radius from PLGS for the airborne pathway. From radiation emissions, this population dose is 2.0 person-millisievert in the liquid pathway and about 1.4 person-millisieverts in the airborne pathway for a population total of 3.4 person-millisieverts. This is insignificant when compared with the population dose of about 320 000 person-millisieverts that this same group receives from natural background radiation and an additional 80 000 person-millisieverts received by some of this population from radiation used in medical treatments.

In the fall of 1999, PLGS began disposing of its non-active waste at the public landfill facility (67 km northwest of PLGS). A monitoring program was established prior to the first shipment.

The Quality Assurance (QA) program faced challenges this year from the elimination of the United States Environmental Protection Agency (USEPA) and Atomic Energy of Canada Limited (AECL) programs. This deficiency was balanced by an increase in other QA activity.

The objectives of the program were met. The program was revised in late 1999, with changes to be implemented in 2000 and described in the report for that year.

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1.0 Introduction

The licence to operate PLGS, issued by the Atomic Energy Control Board (AECB), requires that NB Power maintain an Operational Environmental Radiation Monitoring Program (OERMP) during normal plant operations. This document describes the 1999 results of the program.

The requirement for this program is stated in *Radiation Protection Directives*[1] and *Solid Radioactive Waste Management Facility 1993 Safety Report*[2]. The underlying reason for this is the large inventory of radionuclides that exist on site. The program operates in conjunction with *Liquid and Gaseous Effluent Monitoring Program*[3], which monitors and controls effluents at their source. The Derived Emission Limits (DELs) are calculated in *Derived Emission Limits for Radionuclides in Airborne and Liquid Effluents*[4].

Monitoring of the site began in 1976 with the Pre-operational Program[5], which became the OERMP in 1982[6]. This was implemented when PLGS was declared "in-service" in February, 1983. All radionuclide analyses in 1999 were performed in the Health Physics Environmental/Dosimetry Laboratory at 420 York Street, Fredericton, NB by the three full-time staff members (Health Physicist, Senior Technical Specialist and Technical Specialist).

The radiation monitoring program for PLGS is reviewed annually. This ensures that the samples collected, their frequency of collection, and the analytical techniques used are appropriate to achieve the objectives of the program. Late in 1999, the basis of the OERMP was extensively revised to comply with *Guidelines for Radiological Monitoring of the Environment* [7], which did not exist when this program was first implemented.

The Environmental Radiation Monitoring Program for PLGS fulfils several objectives. These are to:

1) provide an early indication of the appearance or accumulation of any radioactive material in the environment caused by the operation of the station

2) verify the adequacy and proper functioning of station effluent controls and monitoring systems

3) provide an estimate of actual radiation exposure to the surrounding population

4) provide assurance to regulatory agencies and the public that the station's environmental impact is known and within operational targets

5) provide standby monitoring capability for rapid assessment of risk to the general public in the event of unanticipated or accidental releases of radioactive material

6) allow an assessment of the Derived Emission Limit (DEL) calculations based upon empirical rather than theoretical data

The capability of the radiation monitoring laboratory is assessed through the QA program.

Analytical checks are also conducted daily. Indicator radionuclides, for example K-40 in milk, seawater and other samples, show that the analyses are reproducible and that the operation of the laboratory has not changed significantly since it began.

In the fall of 1999, PLGS began disposing of its non-active waste at a public landfill facility (located at Hemlock Knoll, 67 km northwest of PLGS). A monitoring program was established prior to the first shipment. It includes sampling of water from the leachate, bore holes and various holding ponds; sampling of the soil and gamma surveys of the disposal cell surface; and dosimeter placement at key locations.

The following sections will briefly describe the program. Details are provided on PLGS emissions, analyses results, trends, dose estimates, and the quality assurance program.

2.0 Point Lepreau Emission Data

Table 2.01 lists the production performance for PLGS since its beginning. Experience has shown that the years of lower capacity factors are usually the years with the lowest airborne emissions of most radionuclides, especially noble gases. The opposite is true for liquid emissions.

Table 2.01
PLGS Production Performance

Year	*Annual Gross Capacity Factor (%)*
1983	86
1984	90
1985	97
1986	94
1987	92
1988	96
1989	95
1990	96
1991	98
1992	87
1993	95
1994	94
1995	29
1996	83
1997	62
1998	68
1999	74

Lifetime Gross Capacity Factor - 84.5

Emissions from PLGS continue to be at low levels as indicated in Table 2.02. By the time these releases reach the edge of the exclusion zone, they are diluted below the detection limits of most analysis procedures. Laboratory staff monitor the results of the emissions programs so that adjustments can be made to sampling and analyses protocols. There were no unusual emissions during 1999.

Table 2.02
Radionuclides Detected in Effluents - 1999

Nuclide	Gaseous Effluent DEL (Bq/a)	Release (Bq)	Liquid Effluent DEL (Bq/a)	Release (Bq)
H-3	4.3E+17	9.5E+13	1.6E+19	5.3E+13
C-14	3.3E+15	2.8E+11	3.0E+14	2.8E+09
Na-24	5.6E+15		----------	
Ar-41	6.4E+16	2.6E+12	----------	
Sc-46	1.7E+14		----------	
Cr-51	2.4E+16		2.2E+15	2.8E+07
Mn-54	1.1E+14		6.4E+13	1.8E+07
Fe-55	----------		5.1E+14	
Fe-59	4.0E+14		3.1E+13	2.2E+07
Co-58	3.0E+14		7.5E+13	
Co-60	6.5E+12	3.3E+06	1.8E+13	4.6E+08
Zn-65	7.1E+13		1.5E+13	
As-76	----------		3.2E+14	
Kr-85	1.10E+19		----------	
Kr-85m	5.20E+17	5.7E+10	----------	
Kr-87	9.40E+16	1.5E+09	----------	
Kr-88	2.80E+16	3.2E+10	----------	
Sr-89	3.70E+14		4.4E+16	
Sr-90	1.20E+13		2.2E+15	1.3E+06
Y-90	8.20E+15		4.0E+15	
Y-91	----------		3.1E+15	
Zr-95	1.70E+14		3.7E+13	7.4E+08
Nb-95	1.30E+14		1.1E+14	1.6E+09
Mo-99	5.40E+15		1.3E+16	
Ru-103	1.20E+15		1.8E+14	1.4E+07
Ru-106	7.70E+13		2.7E+14	
Ag-110m	3.80E+13		1.8E+13	
Sb-122	----------		1.8E+14	1.5E+07
Sb-124	2.50E+14		4.8E+13	3.3E+07
Sb-125	----------		1.9E+14	3.2E+06
Te-132	1.40E+15		2.9E+13	
I-123	----------		4.2E+16	
I-125	----------		2.3E+14	
I-129	----------		1.9E+13	
I-131	1.00E+13		1.7E+14	
I-132	1.50E+16		2.4E+16	
I-133	4.30E+14		2.3E+15	
I-134	1.90E+16		3.6E+17	
I-135	7.70E+15		9.2E+15	
Xe-131m	9.90E+18		----------	
Xe-133	2.40E+18	2.8E+12	----------	
Xe-133m	2.80E+18		----------	
Xe-135	3.40E+17	1.1E+12	----------	
Xe-135m	2.00E+17	7.8E+09	----------	
Xe-138	2.20E+16	2.7E+10	----------	
Cs-134	1.90E+13		2.5E+14	
Cs-135	----------		3.4E+15	
Cs-136	----------		6.3E+14	
Cs-137	5.40E+12	1.8E+05	4.0E+14	1.4E+06
Ba-140	7.40E+14		9.4E+15	
La-140	1.10E+16		4.7E+14	
Ce-141	2.10E+15		7.4E+14	5.1E+05
Ce-144	1.10E+14		2.8E+14	
Np-239	1.00E+16		----------	
Noble Gas	7.30E+16		----------	
Cu-64	----------		----------	3.3E+07
Sn-113	----------		----------	9.0E+05
Xe-137	----------	1.5E+10	----------	
Gd-153	----------		----------	2.6E+08
Tb-160	----------		----------	6.0E+07
Hf-181	----------		----------	5.1E+05
Alpha	----------		----------	1.9E+07
Beta	----------		----------	1.7E+08

3.0 Sample Media, Locations and Frequency

The data contained in this report are for samples collected from January 1 to December 31, 1999, with some overlap for air and TLD samples. During this time, the major media analysed and their frequency of collection were as indicated in Table 3.01. Sample collection usually takes place at least once each week throughout the year. The number of each sample type and the major radionuclide measurements performed are listed in Table 3.02.

The miscellaneous samples include those which do not readily fit into any of these listed categories or are not routinely collected. These include numerous in-station samples (e.g., drinking water) relating to the operation of PLGS.

The major sample locations are listed in Table 3.03 (details in Appendix C) and shown in Figures 3.02 to 3.05. Each "Indicator" site has a three or four-character identification code (e.g., F01, I00A). An Indicator site is one within the possible influence of PLGS emissions. "Reference" locations, chosen to lie outside the influence of PLGS emissions, are identified by the letter R at the end of the location code (e.g., A01R).

Sample locations for mobile seafood species (lobster, fish, etc.) caught in the Point Lepreau area are specified as accurately as reasonably possible. The location of capture, however, may bear little relationship to where the animal has been in the recent past. The availability of such samples is not generally predictable and is outside of the control of the laboratory.

Table 3.01
Schedule Of Sample Collection and Analysis

SampleMedia	*Typical Frequency*
Atmospheric Monitoring	
Airborne Particulates	Monthly (Integrated sample)
Airborne Radioiodines	Monthly (Integrated sample)
Airborne Tritium	Monthly (Integrated sample)
Airborne C-14	Monthly (Integrated sample)
Ambient Gamma (TLDs)	Quarterly (Integrated sample)
Airborne Radiostrontiums (GEM)	Weekly Composite (Integrated sample)
Terrestrial Monitoring	
Milk - commercial dairy	Monthly
- dairy farms	Quarterly
Well Water	Semi-annually
Other Water	Quarterly
Ambient Gamma (TLDs)	Quarterly (Integrated sample)
Berries	As Available
Garden Vegetables	As Available
Vegetation	Quarterly
Soil	Quarterly
Precipitation	Monthly (Integrated sample)
Marine Monitoring	
Seawater	Quarterly
Clams	As Available
Fish	As Available
Lobster	As Available
Periwinkles	As available
Aquaculture Salmon	As Available
Scallops	As Available
Crab	As Available
Dulse	As Available
Other Sea Plants	Quarterly
Sediment	Quarterly
Gamma Surveys (Beaches)	Quarterly
Liquid Radiostrontiums (LEM)	Monthly Composite (Integrated sample)
Solid Radioactive Waste Management Facility	
Bore Holes	Quarterly
Parshall Flumes	Weekly
Ambient Gamma (TLDs)	Quarterly (Integrated sample)

Table 3.02
Sample Information

Sample Media	*Number of Samples*	*Radionuclide Measurements*
Atmospheric Monitoring		
Airborne Particulates	96	gamma emitters & gross alpha/beta
Airborne Radioiodines	96	I-131,133,135 etc.
Airborne Tritium	96	H-3
Airborne Carbon-14	36	C-14
Ambient Gamma (TLDs)	155	gamma exposure
Airborne Radiostrontiums (GEM)	52	Sr-89,90
Terrestrial Monitoring		
Milk	23	gamma emitters & H-3
Well Water	22	gamma emitters, gross alpha/beta, H-3
Pond/Surface/Puddle Water	18	gamma emitters & H-3
Ambient Gamma (TLDs)	see *Atmospheric Monitoring*	gamma exposure
Berries	7	gamma emitters
Garden Vegetables	35	gamma emitters
Vegetation	17	gamma emitters
Soil	8	gamma emitters
Precipitation	44	gamma emitters & H-3
Marine Monitoring		
Seawater	22	gamma emitters & H-3
Clams	14	gamma emitters
Fish	0	gamma emitters
Lobster	8	gamma emitters
Periwinkles	14	gamma emitters
Aquaculture Salmon	3	gamma emitters
Scallops	3	gamma emitters
Crab	2	gamma emitters
Dulse	7	gamma emitters
Other Sea plants	15	gamma emitters
Sediment	40	gamma emitters
Gamma Surveys (Beaches)	40	gamma dose rate
Liquid Radiostrontiums (LEM)	12	Sr-89,90
Solid Radioactive Waste Management Facility		
Bore Holes	60	gamma emitters & H-3
Parshall Flumes	106	gamma emitters & H-3
Ambient Gamma (TLDs)	172	gamma exposure

Table 3.02 (continued)
Sample Information

Sample Media	*Number of Samples*	*Radionuclide Measurement*
Hemlock Knoll Regional Sanitary Landfill		
Water	123	gamma emitters & H-3
Soil	16	gamma emitters
Ambient Gamma (TLDs)	10	gamma exposure
Gamma Surveys	40	gamma dose rate
Other		
Miscellaneous	90	as required
Quality Assurance (external)	0	as required

Table 3.03
General Location Codes

Code	*Location*
A	West of Pennfield Ridge
B	Pennfield to New River Beach (inclusive)
C	Lepreau and Lepreau Harbour
D	Little Lepreau and Little Lepreau Basin
E	Maces Bay
F	Welch Cove
G	Pt. Lepreau lighthouse and surrounding area
H	Duck Cove
I	PLGS site – northeast quadrant
J	PLGS site – southeast quadrant
K	PLGS site – southwest quadrant
L	PLGS site – northwest quadrant
M	PLGS
N	Dipper Harbour
P	East of Dipper Harbour East to Musquash
Q	Lorneville
S	Saint John and surrounding area
T	Taymouth
X	Fredericton and surrounding area
Y	Hemlock Knoll Regional Sanitary Landfill

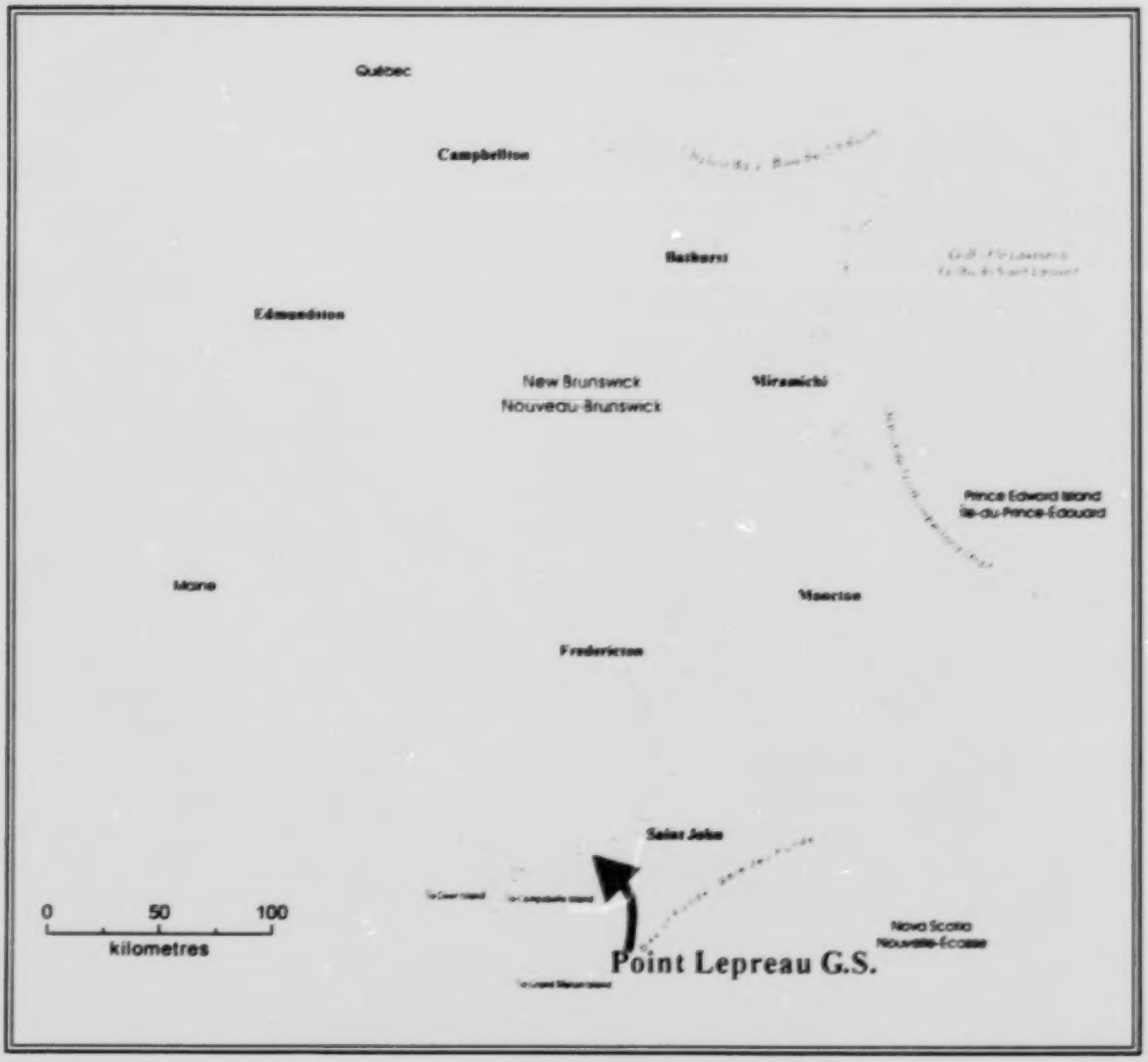

Figure 3.01
Map of Region

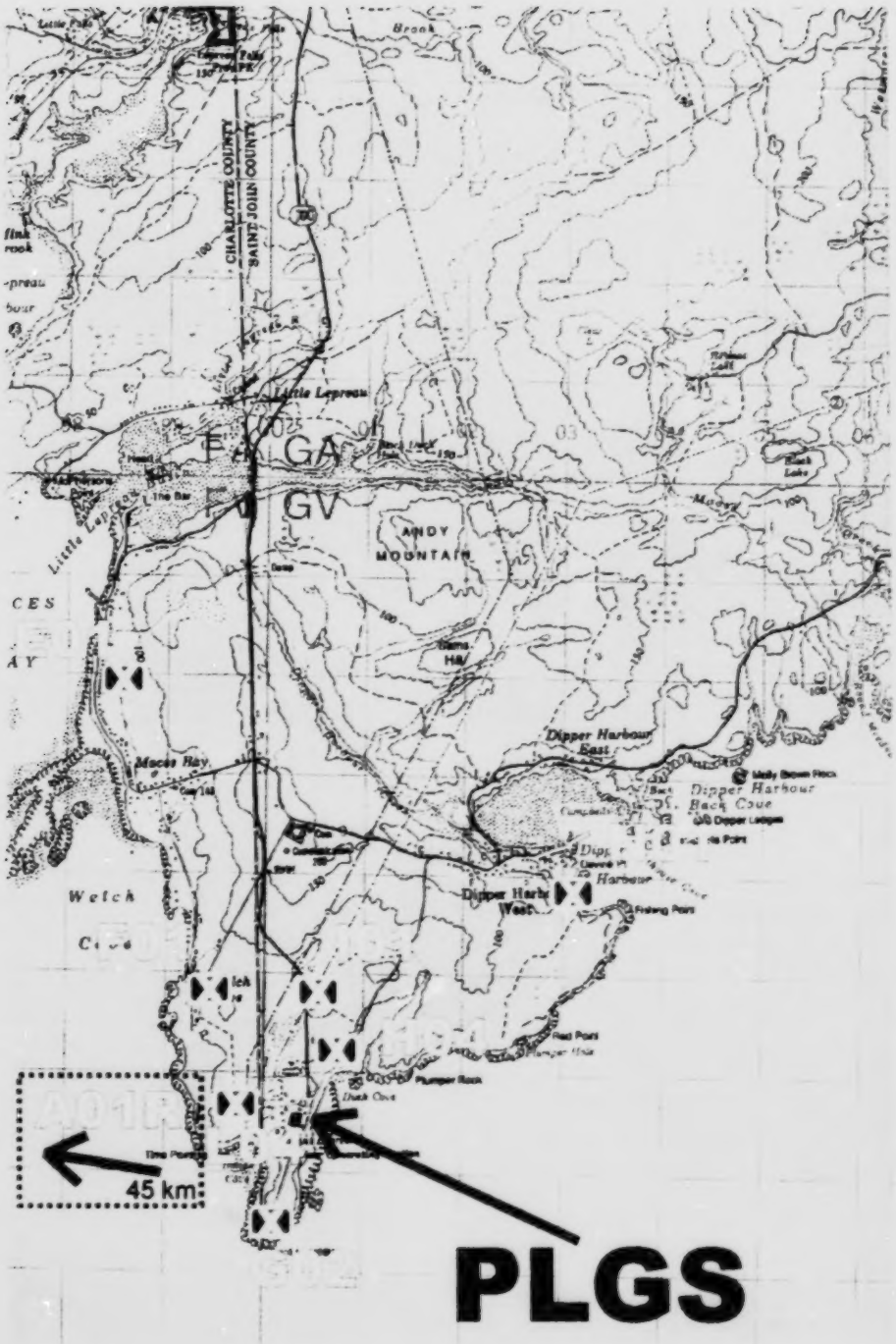

Figure 3.02

Air Monitoring Stations

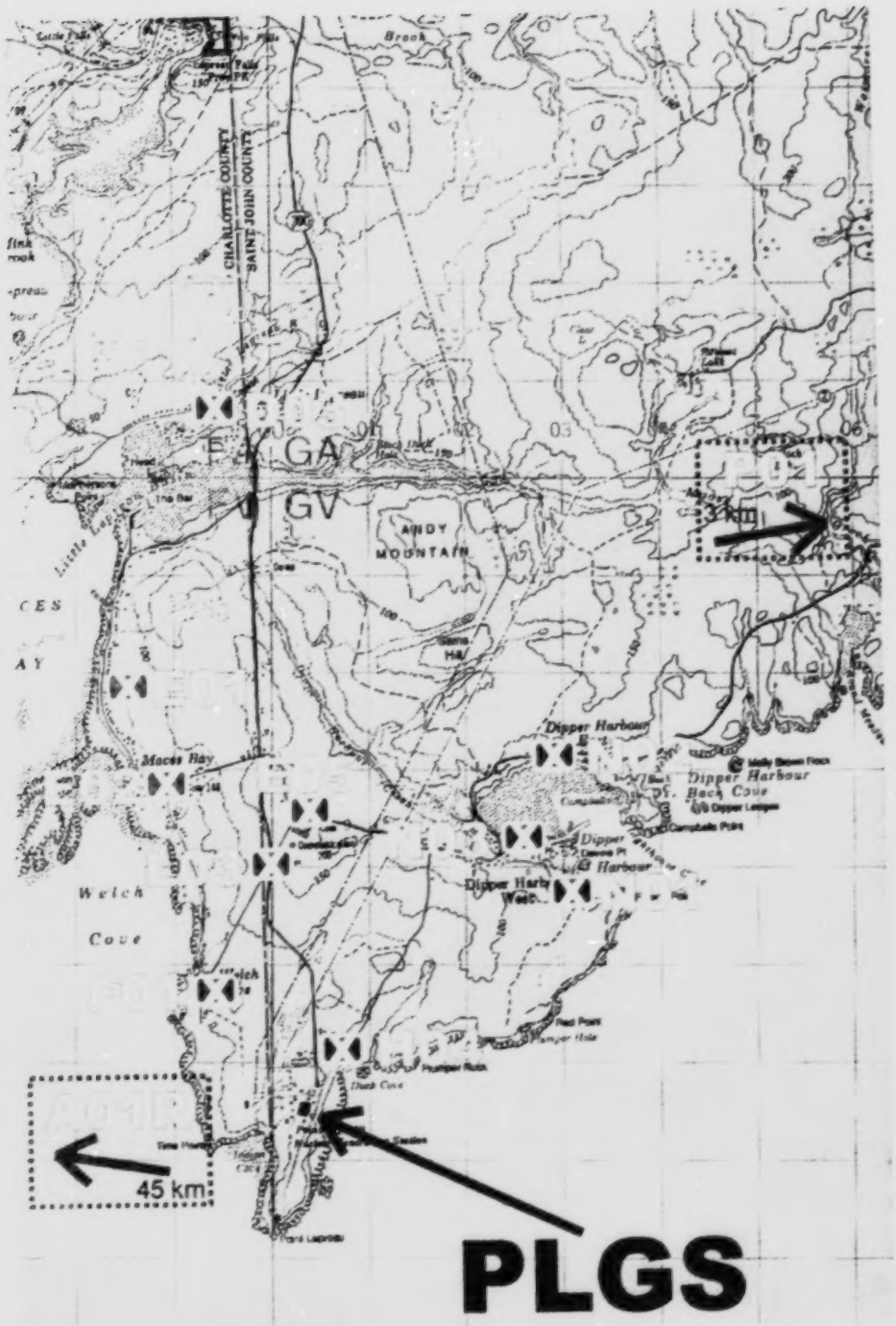

Figure 3.03

Well Water Sites

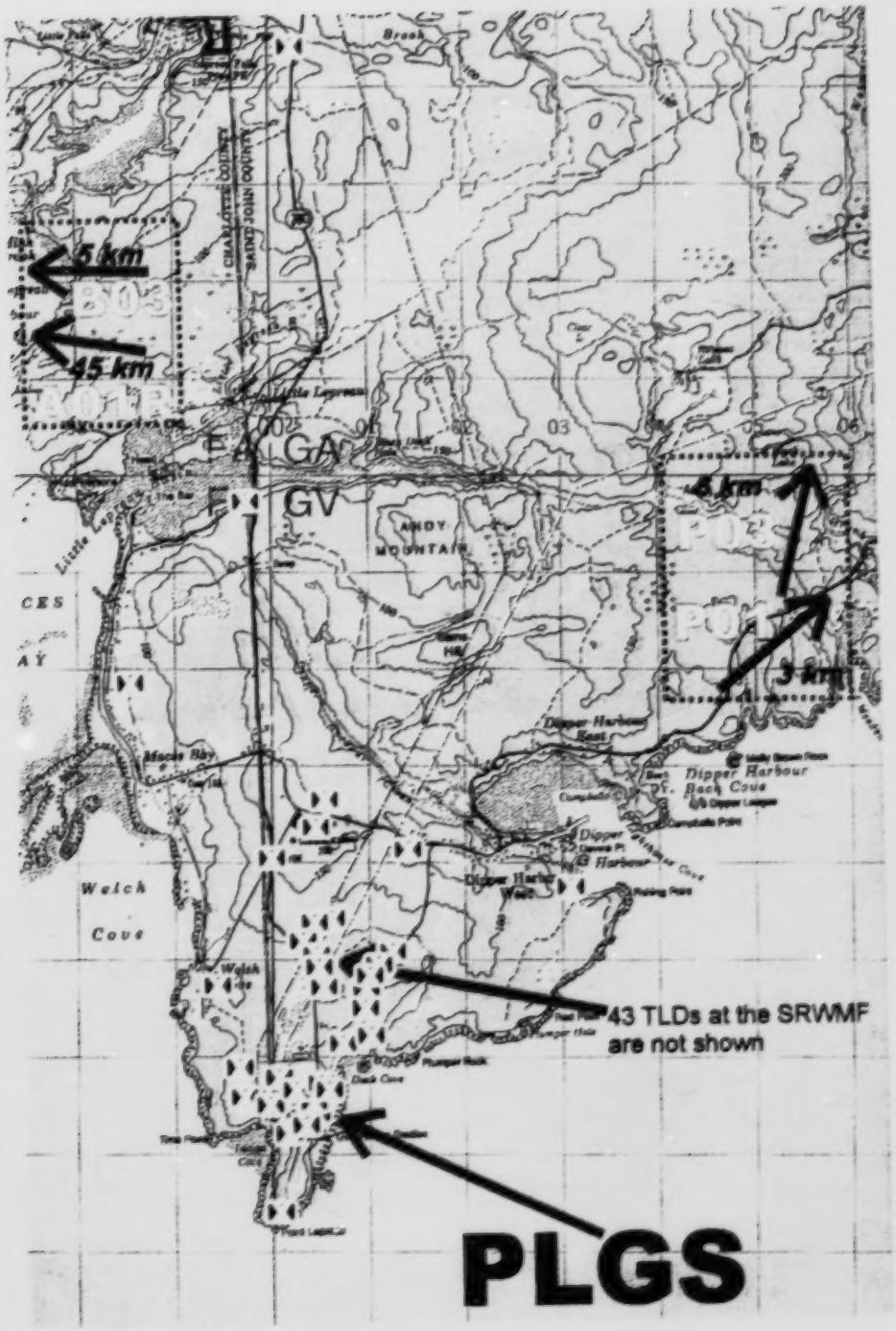

Figure 3.04

TLD Sites

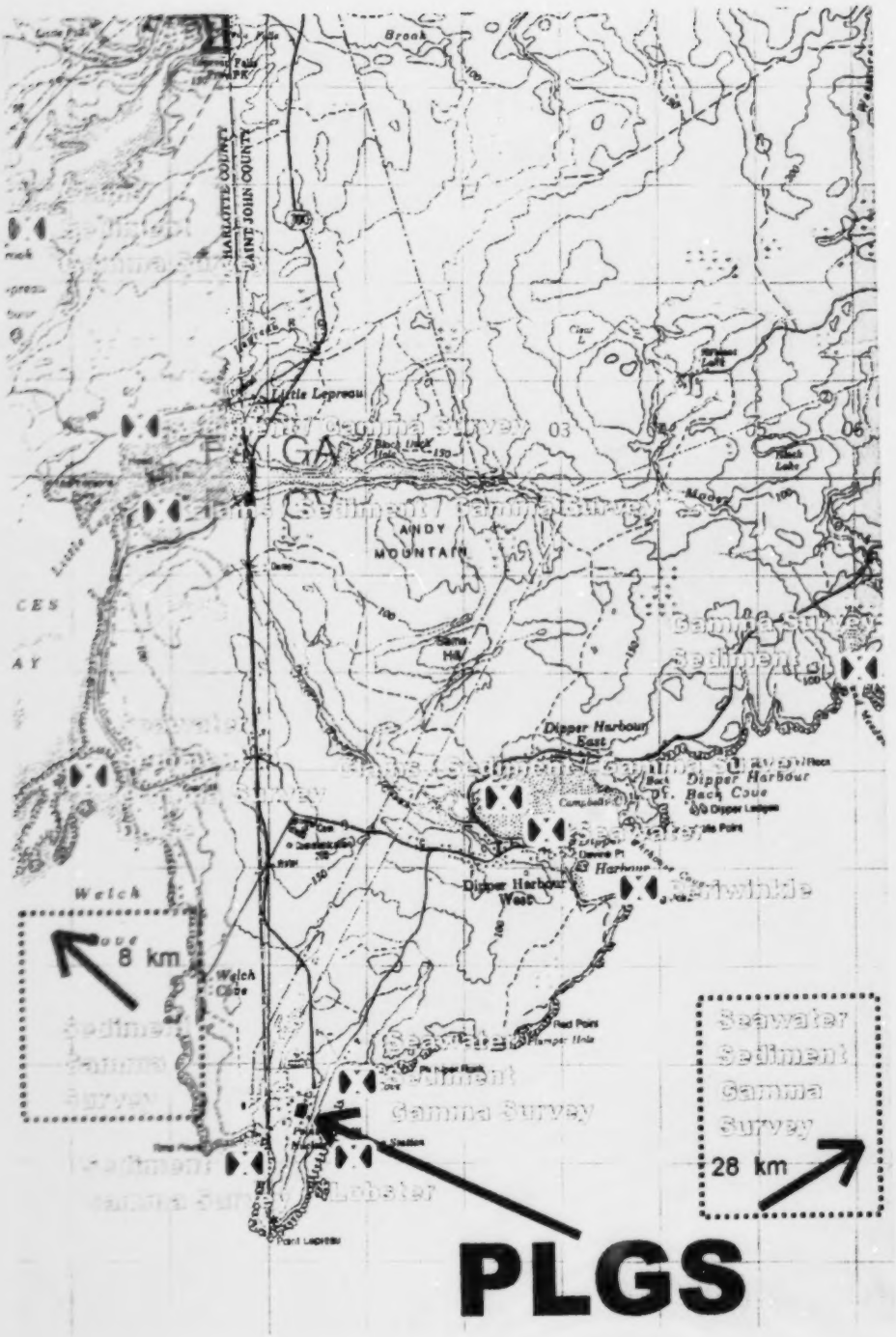

Figure 3.05

Marine Monitoring Sites

4.0 Summary and Discussion of Data

The following is a summary and discussion of the data on environmental samples collected for 1999.

Most samples contained detectable levels of naturally occurring (K-40) or cosmogenic (Be-7) radionuclides. Some contained Cs-137 (soils, sediments, lichen) from the atmospheric bomb tests of past years and the Chernobyl accident. The only radionuclide originating from PLGS that is detected consistently is tritium (in air and fresh water). In 1999, analyses that indicated emissions traceable to PLGS were:

1) H-3 in airborne water vapour and fresh water

2) H-3 in Parshall flume and bore hole water from the Solid Radioactive Waste Management Facility (SRWMF)

3) TLD measurements at onsite locations

The only assessable radiation dose from PLGS on the local population is that from tritiated water vapour in air. Outside the 1 km boundary, the activity of H-3 in air ranges from less than about 2E-2 Bq/m^3 (below the lower limit of detection by the method used) to about 5E-1 Bq/m^3 of air. The natural concentration of H-3 is up to 0.7 Bq/L in most surface waters and up to 1E-3 Bq/m^3 in air. The natural concentration of C-14 in the atmosphere is about 4E-2 Bq/m^3. Such levels are usually below the lower limit of detection of the extremely sensitive analytical methods used in the monitoring program. Detectable values usually indicate additional contributions from the operation of PLGS.

Only detected radionuclides are listed in the following tables. Refer to Tables 1 to 11 in Appendix A for detailed listings of detection limits. Most tables contain the following data:

Column 1 - Shows the type of analysis or nuclide and, in parentheses, the total number of samples analysed.

Column 2 - Shows the mean of the Critical Levels (CLs) for all samples and, in parentheses, the range of the CLs. Any measurement greater than the CL is considered detected at the 99% confidence level (an explanation of the statistical protocol is given in Appendix A).

Column 3 - Shows the mean of the detected values (i.e., values exceeding the CL) for all Indicator stations, followed in parentheses by the ratio (F) of the number of detected values to the total number of Indicator samples. The second line of the column indicates the range of detected values for the Indicator stations.

Column 4 - Shows the location code for the Indicator station with the largest mean value. Refer to Appendix C for sample locations.

Column 5 - Shows the mean of detected values for the Indicator station with the largest mean value, followed in parentheses by the ratio (F) of the number of detected values to the total number of samples for this Indicator station. The second line of this column contains the range of detected values for this location.

Column 6 - Shows the mean of detected values at the Reference location(s), followed in parentheses by the ratio (F) of detected values to the total number of samples at this location. The second line of this column contains the range of detected values for the Reference location(s).

4.1 Airborne Particulates

In 1999, there were no detectable airborne particulate radionuclides that could be attributed to the operation of PLGS on any of the 96 samples analysed.

Air is continuously monitored from the eight locations shown in Figure 3.02. Once a month the filters are changed and analysed. There were no collection days lost in 1999, although it is not uncommon to lose some due to mechanical or electrical problems.

Gross alpha and gross beta measurements are an indication of total activity in the environment. This includes naturally occurring (potassium-40), cosmogenic (beryllium-7), and man-made sources of radiation. Table 4.01 is a summary of these detected radionuclides. Figures 4.01 and 4.02 show the gross beta results for each location throughout the year. While there is a slight seasonal trend, there is no difference between onsite and offsite results.

Table 4.01
Airborne Particulates
(Bq/m^3)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
ALPHA (96)	2.9E-006 (1.1E-006 -9.6E-006)	2.4E-005 (84/84) (5.6E-006 -8.2E-005)	G02	4.1E-005 (12/12) (1.4E-005 -8.2E-005)	2.0E-005 (12/12) (8.7E-006 -3.3E-005)
BETA (96)	6.4E-006 (2.1E-006 -2.2E-005)	2.8E-004 (84/84) (8.1E-005 -1.0E-003)	G02	4.2E-004 (12/12) (1.4E-004 -1.0E-003)	2.7E-004 (12/12) (1.4E-004 -4.8E-004)
Be-7 (96)	2.0E-004 (3.0E-005 -1.0E-003)	1.9E-003 (83/84) (6.2E-004 -3.5E-003)	G02	2.4E-003 (12/12) (1.2E-003 -3.3E-003)	1.8E-003 (12/12) (8.7E-004 -3.1E-003)
K-40 (96)	5.9E-004 (1.8E-004 -1.9E-003)	3.7E-004 (1/84) (3.7E-004 -3.7E-004)	I01	3.7E-004 (1/12) (3.7E-004 -3.7E-004)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

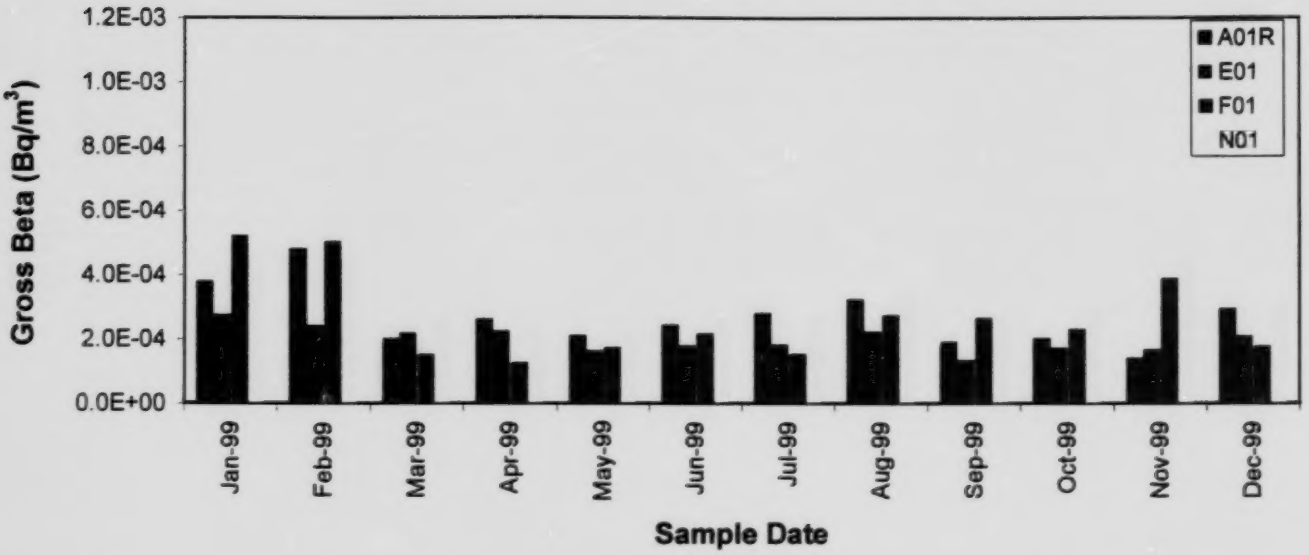

Figure 4.01
Gross Beta in Air for Each Offsite Air Station

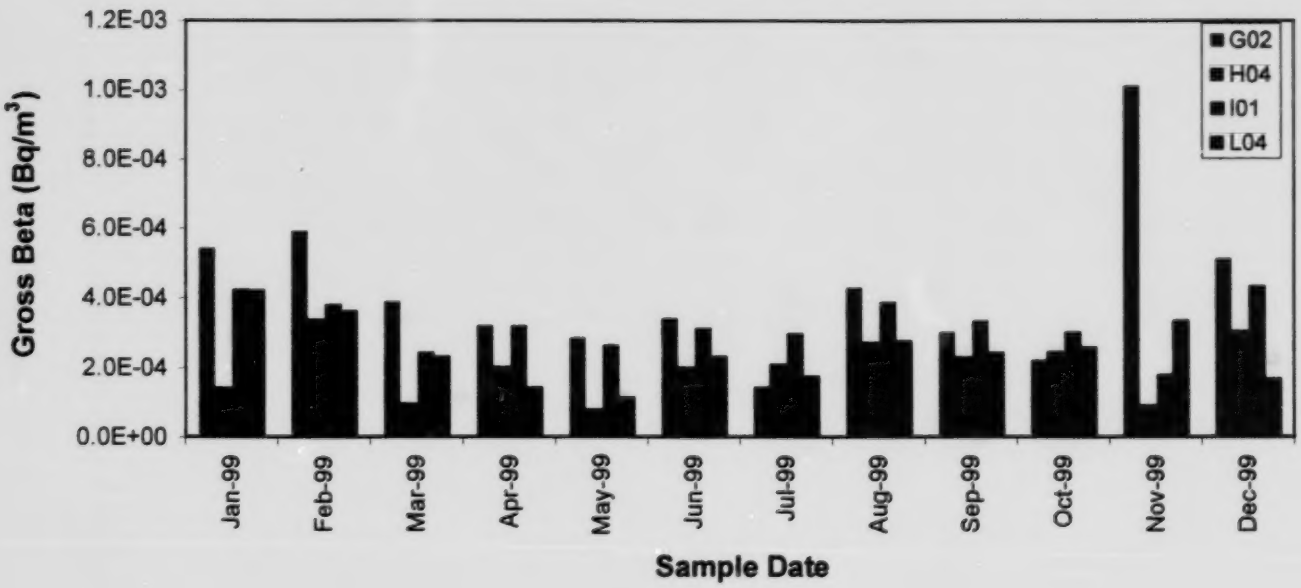

Figure 4.02
Gross Beta in Air for Each Onsite Air Station

4.2 Airborne Radioiodines

Iodine-131 was consistently below the Critical Level (average 8E-6 Bq/m^3) on the 96 samples analysed.

Air is monitored continuously from the eight locations shown in Figure 3.02. Once a month the cartridges are changed and analysed. There were no collection days lost in 1999, although it is not uncommon to lose some due to mechanical or electrical problems.

The results are consistent with the fact that I-131 was not detected in the emissions from PLGS.

4.3 Airborne Tritium

Tritium was detected in 75 of the 84 samples collected from the air monitoring stations on the Point Lepreau peninsula in 1999, and was not detected in the 12 samples at the reference location.

Air is monitored continuously from the eight locations shown in Figure 3.02. Once a month the molecular sieve bombs are changed and analysed. There were no collection days lost in 1999, although it is not uncommon to lose some due to mechanical or electrical problems.

The maximum concentration of tritium in air on site was less than 3 Bq/m^3 of air. Off site it reached 0.5 Bq/m^3. Tritium has been detected from time to time at the reference location, even before PLGS became operational.

Table 4.02 is the summary table of 1999 tritium data and Table 4.03 gives details of 1999 tritium results by location (graphically shown in Figures 4.03 and 4.04). Locations to the northeast (H04, I01 and N01) have elevated H-3 measurements in the warmer months due to the predominant summer wind direction which changes in the winter to impact the southwest locations (G02 and L04).

Table 4.02
Airborne Tritium
(Bq/m^3)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Highest Indicator Station Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (96)	4.7E-002 (1.5E-002 -1.3E-001)	5.7E-001 (75/84) (3.0E-002 -3.0E+000)	I01	1.5E+000 (12/12) (4.0E-001 -3.0E+000)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

Table 4.03
Airborne Tritium
(Bq/m^3)

Collection Start Date	A01R Bocabec	E01 Maces Bay	F01 Welch Cove	G02 Lepreau Lighthouse	H04 Information Centre	I01 SRWMF	L04 Construction Stores	N01 Dipper Harbour
+	## 44.7	4.5	1.6	1.0	0.8	1.2	0.6	3.7
1999-01-06	<3.6E-002	3.2E-002	5.0E-002	5.3E-001	7.4E-001	1.6E+000	1.4E+000	3.1E-002
1999-02-02	<2.4E-002	<1.9E-002	1.2E-001	4.1E-001	9.1E-001	4.0E-001	6.9E-001	3.0E-002
1999-02-22	<4.4E-002	<4.6E-002	6.3E-002	5.4E-001	1.2E+000	1.5E+000	8.8E-001	8.3E-002
1999-03-24	<2.2E-002	<1.9E-002	<3.3E-002	2.1E-001	3.2E-001	6.4E-001	1.6E-001	4.5E-002
1999-05-04	<3.4E-002	4.1E-002	1.2E-001	4.0E-002	6.5E-001	6.9E-001	7.4E-001	1.3E-001
1999-06-08	<4.9E-002	5.2E-002	1.1E-001	6.0E-002	7.2E-001	6.7E-001	9.9E-002	1.2E-001
1999-07-07	<4.2E-002	8.0E-002	7.1E-002	<4.1E-002	5.1E-001	1.0E+000	1.8E-001	2.3E-001
1999-08-12	<8.5E-002	<1.3E-001	8.5E-002	<1.5E-001	2.1E+000	3.0E+000	1.2E-001	4.6E-001
1999-09-14	<2.6E-001	6.6E-002	1.1E-001	3.8E-001	1.8E+000	2.7E+000	3.7E-001	1.3E-001
1999-10-05	<7.2E-002	<4.1E-002	1.3E-001	3.5E-001	2.1E+000	2.7E+000	2.6E-001	2.5E-001
1999-11-02	<4.8E-002	<8.8E-002	2.8E-001	3.1E-001	1.1E+000	1.5E+000	2.5E-001	6.9E-002
1999-12-07	<2.8E-002	5.9E-002	1.3E-001	8.3E-001	4.7E-001	1.4E+000	5.0E-001	8.1E-002

\+ : The sample collection periods are approximately four weeks in duration, so there are either 12 or 13 periods in the year. All sample stations are changed at the same time. The start date is the stop date for the previous sample.

: Approximate distance from Point Lepreau G.S. (km).

SRWMF - Solid Radioactive Waste Management Facility

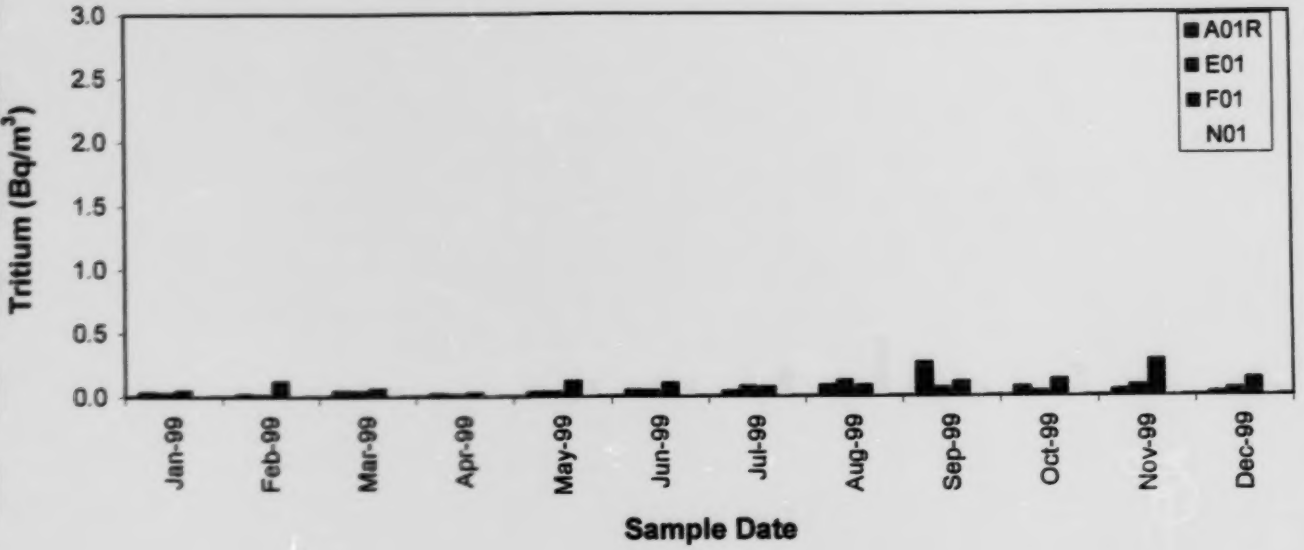

Figure 4.03
Airborne Tritium for Each Offsite Air Station

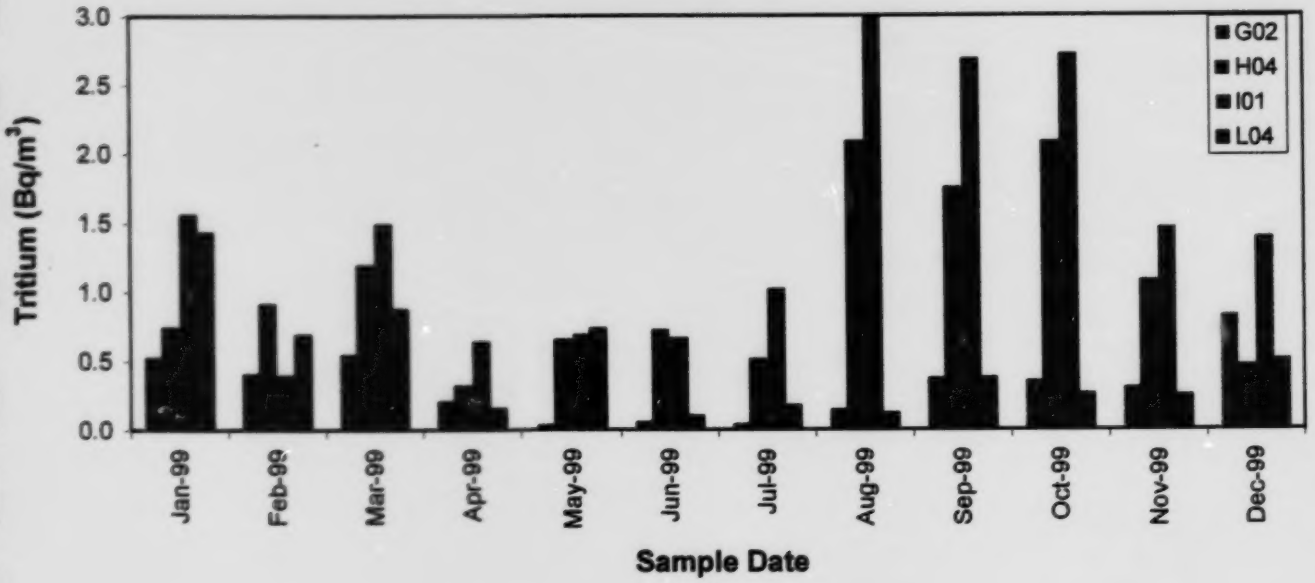

Figure 4.04
Airborne Tritium for Each Onsite Air Station

4.4 Airborne Carbon-14

C-14 was consistently below the Critical Level (3E-1 Bq/m^3) on the 36 samples analysed.

Air is monitored continuously at two onsite locations (G02 and H04 in Figure 3.02) and one reference location. The caustic bubblers are changed monthly and returned to the lab for analysis. One sample (the reference sample for September) was impacted due to equipment adjustment problems. This resulted in low sample volume for the month and a high LLD.

Individual analysis results for 1999 are given in Table 4.04. Based on stack emissions, the calculated average annual concentration of C-14 in air at the boundary fence for 1999 was approximately 9E-4 Bq/m^3 (well below the typical lower limit of detection for C-14 at this time and well below the natural level of 4E-2 Bq/m^3). A more sensitive method will be introduced in 2000 which will decrease the LLD by almost a factor of ten.

Table 4.04
Airborne Carbon-14
(Bq/m^3)

Collection Start Date +	G02 Lepreau Lighthouse	H04 Information Centre	X03R Fredericton Laboratory
1999-01-06	<2.3E-001	<2.3E-001	<5.8E-001
1999-02-02	<4.3E-001	<4.7E-001	<4.7E-001
1999-02-22	<3.0E-001	<3.5E-001	<3.6E-001
1999-03-24	<2.4E-001	<2.6E-001	<1.8E-001
1999-05-04	<1.8E-001	<2.9E-001	<2.4E-001
1999-06-08	<1.7E-001	<1.9E-001	<2.2E-001
1999-07-07	<1.6E-001	<2.2E-001	<1.5E-001
1999-08-12	<2.1E-001	<1.8E-001	<2.8E-001
1999-09-14	<4.0E-001	<2.9E-001	<9.5E-001
1999-10-05	<4.3E-001	<3.3E-001	<2.9E-001
1999-11-02	<3.6E-001	<3.0E-001	<2.9E-001
1999-12-07	<2.4E-001	<2.1E-001	<2.5E-001

+ : The sample collection periods are approximately four weeks in duration, so there are either 12 or 13 periods in the year. The two indicator stations are changed at the same time.

4.5 Ambient Gamma (TLD)

Gamma exposure measurements were slightly higher onsite, especially near the SRWMF and reactor building, than they were offsite.

Ambient gamma radiation is measured by thermoluminescent dosimeters (TLDs) at the 82 locations shown in Figure 3.04 plus five locations at the Hemlock Knoll Regional Sanitary Landfill (locations YTL1 to YTL5). Forty three of these are near the Solid Radioactive Waste Management Facility. Locations I00A - I00L are on the perimeter fence of the SRWMF-Phase 1, and locations I03A -I03L are on the perimeter of the SRWMF-Phase 2. The Drop Off TLDs for SRWMF-Phase 2 are shown in Table 4.29. TLDs are changed quarterly. All but one of the 338 dosimeters placed in the environment were recovered.

Data for 1999 are given in Table 4.05. The data in the "Total" column are rounded to the nearest ten microgray. If a quarterly measurement is not available (lost or vandalised TLD, animal damage, moisture penetration, etc.) a mean value is calculated from the available measurements in order to provide an estimate for the annual total. The statistical uncertainty shown in the Total column is the square root of the sum of the squares of the uncertainties of the individual quarterly measurements.

The variation in natural background radiation at any individual location covers a range of about 300 microgray from year to year. A few locations close to the reactor building (e.g. J70) and the air emissions stack show significant, but small, increases in gamma radiation due to chronic releases of low levels of noble gases. Small increases at the SRWMF locations are due to low-level waste and used fuel emplacement, and not to station emissions. There is a small, but undefinable, component of radiation on the TLDs at the SRWMF that is due to enhanced natural radiation from the aggregate in the concrete structures.

Figure 4.05 compares the reference location results with the results for other locations.

The range of values for the 12 TLD locations at the SRWMF - Phase 2 was from 720 to 1350 microgray per annum. The average for the facility is 870 microgray per annum - not significantly different from other low background (and natural) radiation measurements anywhere in Canada.

Table 4.05
TLD, Environmental
(µGy)

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
A01R	143 +- 14	160 +- 16	153 +- 15	167 +- 17	620 +- 30
B03	146 +- 15	169 +- 17	166 +- 17	177 +- 18	660 +- 30
C03	135 +- 13	151 +- 15	151 +- 15	189 +- 19	630 +- 30
D02	153 +- 15	182 +- 18	167 +- 17	212 +- 21	710 +- 40
E01	139 +- 14	159 +- 16	153 +- 15	164 +- 16	610 +- 30
E04	145 +- 15	114 +- 11	101 +- 10	139 +- 14	500 +- 30
E05	144 +- 14	161 +- 16	139 +- 14	190 +- 19	630 +- 30
E06	200 +- 20	193 +- 19	187 +- 19	219 +- 22	800 +- 40
F01	123 +- 12	142 +- 14	141 +- 14	144 +- 14	550 +- 30

Table 4.05 (continued)
TLD, Environmental
(µGy)

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
G02	180 +- 18	186 +- 19	172 +- 17	197 +- 20	730 +- 40
H04	146 +- 15	145 +- 15	151 +- 15	166 +- 17	610 +- 30
H05	113 +- 11	134 +- 13	115 +- 11	162 +- 16	520 +- 30
100A	209 +- 21	236 +- 24	216 +- 22	267 +- 27	930 +- 50
100B	223 +- 22	241 +- 24	223 +- 22	277 +- 28	960 +- 50
100C	221 +- 22	238 +- 24	211 +- 21	262 +- 26	930 +- 50
100D	209 +- 21	229 +- 23	204 +- 20	258 +- 26	900 +- 50
100E	209 +- 21	226 +- 23	214 +- 21	253 +- 25	900 +- 50
100F	212 +- 21	236 +- 24	214 +- 21	265 +- 26	930 +- 50
100G	219 +- 22	229 +- 23	221 +- 22	274 +- 27	940 +- 50
100H	227 +- 23	240 +- 24	235 +- 24	280 +- 28	980 +- 50
100I	230 +- 23	235 +- 24	229 +- 23	277 +- 28	970 +- 50
100J	224 +- 22	244 +- 24	224 +- 22	267 +- 27	960 +- 50
100K	207 +- 21	217 +- 22	216 +- 22	258 +- 26	900 +- 50
100L	196 +- 20	226 +- 23	201 +- 20	255 +- 25	880 +- 40
103A	182 +- 18	186 +- 19	177 +- 18	230 +- 23	780 +- 40
103B	176 +- 18	190 +- 19	178 +- 18	228 +- 23	770 +- 40
103C	160 +- 16	184 +- 18	167 +- 17	213 +- 21	720 +- 40
103D	257 +- 26	280 +- 28	296 +- 30	369 +- 37	1200 +- 60
103E	319 +- 32	335 +- 33	335 +- 34	365 +- 36	1350 +- 70
103F	193 +- 19	218 +- 22	200 +- 20	251 +- 25	860 +- 40
103G	177 +- 18	183 +- 18	165 +- 16	206 +- 21	730 +- 40
103H	198 +- 20	208 +- 21	191 +- 19	236 +- 24	830 +- 40
103I	178 +- 18	187 +- 19	179 +- 18	231 +- 23	780 +- 40
103J	193 +- 19	209 +- 21	191 +- 19	236 +- 24	830 +- 40
103K	184 +- 18	204 +- 20	183 +- 18	232 +- 23	800 +- 40
103L	175 +- 17	181 +- 18	176 +- 18	216 +- 22	750 +- 40
175	236 +- 24	198 +- 20	189 +- 19	227 +- 23	850 +- 40
186	143 +- 14	155 +- 15	141 +- 14	181 +- 18	620 +- 30
187	149 +- 15	173 +- 17	158 +- 16	197 +- 20	680 +- 30
188	162 +- 16	176 +- 18	161 +- 16	203 +- 20	700 +- 40
189	160 +- 16	176 +- 18	161 +- 16	201 +- 20	700 +- 40
190	116 +- 12	141 +- 14	121 +- 12	167 +- 17	540 +- 30
191	132 +- 13	161 +- 16	150 +- 15	NA	590 +- 30
192	141 +- 14	154 +- 15	143 +- 14	185 +- 19	620 +- 30
193	126 +- 13	144 +- 14	135 +- 13	180 +- 18	590 +- 30
194	163 +- 16	187 +- 19	171 +- 17	214 +- 21	740 +- 40
195	151 +- 15	147 +- 15	136 +- 14	171 +- 17	600 +- 30
198	149 +- 15	169 +- 17	143 +- 14	196 +- 20	660 +- 30
199	172 +- 17	197 +- 20	173 +- 17	211 +- 21	750 +- 40
J00	158 +- 16	187 +- 19	162 +- 16	205 +- 20	710 +- 40
J20	169 +- 17	181 +- 18	166 +- 17	211 +- 21	730 +- 40
J35	176 +- 18	182 +- 18	169 +- 17	212 +- 21	740 +- 40
J70	306 +- 31	218 +- 22	267 +- 27	352 +- 35	1140 +- 60
K01	165 +- 17	189 +- 19	178 +- 18	223 +- 22	750 +- 40
K02	179 +- 18	192 +- 19	171 +- 17	214 +- 21	760 +- 40
L01	144 +- 14	169 +- 17	154 +- 15	189 +- 19	660 +- 30
L02	205 +- 20	229 +- 23	207 +- 21	247 +- 25	890 +- 40
L03	140 +- 14	150 +- 15	127 +- 13	171 +- 17	590 +- 30
L04	171 +- 17	185 +- 19	180 +- 18	195 +- 20	730 +- 40
M02	261 +- 26	261 +- 26	238 +- 24	286 +- 29	1050 +- 50
N01	143 +- 14	157 +- 16	165 +- 17	183 +- 18	650 +- 30
P01	102 +- 10	115 +- 11	89 +- 9	142 +- 14	450 +- 20
P03	110 +- 11	138 +- 14	132 +- 13	177 +- 18	560 +- 30
YTL1	NA	NA	112 +- 11	161 +- 16	550 +- 20
YTL2	NA	NA	113 +- 11	161 +- 16	550 +- 20
YTL3	NA	NA	90 +- 9	143 +- 14	470 +- 20
YTL4	NA	NA	86 +- 9	144 +- 14	460 +- 20
YTL5	NA	NA	147 +- 15	216 +- 22	730 +- 30

NA : Data not Available - Lost or destroyed TLD, or site not in use for this collection interval.

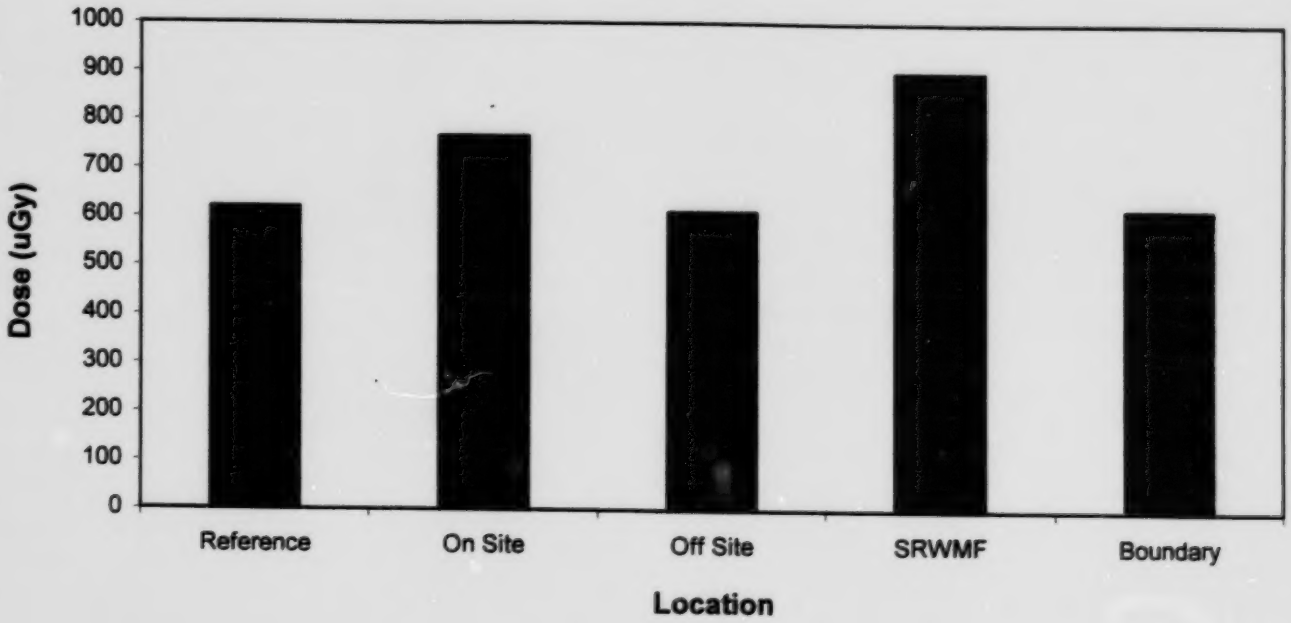

Figure 4.05
Mean TLD Results for 1999

4.6 Airborne Radiostrontiums (GEM)

Since Sr-89,90 emissions are so low, the expected concentration in environmental samples is well below the detection limit.

PLGS gaseous emissions are monitored continuously at their source by the Gaseous Effluent Monitor (GEM). The filters are changed daily and the weekly composite is sent to the lab for analysis. Fifty two sets of these filters were analysed for Sr-89,90. If the release rate warrants, or if significant beta activity is detected in environmental air samples, a Sr-89,90 analysis is performed on those samples.

Strontium-89,90 were not detected in PLGS emissions in 1999.

4.7 Milk

There were no detected radionuclides in milk attributed to PLGS operations.

Milk from a commercial dairy is purchased each month from a supermarket in Fredericton (one sample was missed in the spring). Additional milk from herds in the South of the province is analysed where possible. All samples are analysed for gamma emitting radionuclides and tritium. There are no commercial herds or individual cows producing milk in the Point Lepreau area. The closest herds to PLGS are in Oak Bay (60 km distant), Fredericton Junction (70 km distant), and Hammond River (60 km distant), and the milk from these locations is analysed quarterly or as available.

Table 4.06 is a summary of the detected radionuclides in milk. Cesium-137 was detected in two of the 23 samples collected, at an average concentration of 0.11 Bq/L. The Cs-137 originated from fallout from bomb tests and the Chernobyl accident. Cesium is preferentially absorbed by the cow if there is a dietary deficiency in potassium. Naturally occurring radionuclides (including K-40 at about 50 Bq/L and, occasionally, progeny of uranium and thorium) are also detected in milk. As airborne emissions from PLGS are monitored continuously, and were insignificant all year, neither tritium nor gamma emitting radionuclides attributable to the operation of PLGS would be expected to be detected in these milk samples.

Table 4.06
Milk
(Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Cs-137 (23)	5.0E-002 (3.7E-002 -9.1E-002)	1.1E-001 (2/11) (7.7E-002 -1.4E-001)	A11	1.4E-001 (1/4) (1.4E-001 -1.4E-001)	*
K-40 (23)	5.6E-001 (6.4E-002 -3.5E+000)	5.1E+001 (11/11) (4.9E+001 -5.5E+001)	S10	5.3E+001 (4/4) (5.2E+001 -5.5E+001)	5.2E+001 (12/12) (5.0E+001 -5.4E+001)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.8 Well Water

No gamma emitting radionuclides other than those occurring in nature from radon progeny were detected in well water. The beta activity is due to the presence of naturally occurring radionuclides peculiar to certain locations. The H-3 in seven of the 22 samples is most likely due to surface runoff into shallow wells. The source of this H-3 is PLGS emissions.

Water is collected semi-annually from the 11 wells shown in Figure 3.03. Two of these wells are onsite.

Table 4.07 is a summary of the detected radionuclides in well water. Figures 4.06 and 4.07 show the gross beta and H-3 results for each sample. "Less Than" values are plotted for non-detected results. The H-3 measurements were made after samples had been allowed to sit for up to two weeks to avoid radioactive interference from the relatively abundant, but short half-life, radon progeny which are common in most well waters. Tritium originates in the washout into precipitation and subsequent drainage into some of the wells. Rainwater analyses indicate H-3 concentrations ranging from 12 to 220 Bq/L in 36 of 44 samples.

The 1996 Guidelines for Canadian Drinking Water Quality recommend 7 000 Bq/L as the maximum acceptable concentration for H-3 in drinking water. The highest average well water H-3 content was less than one percent of the recommended maximum concentration.

As a special project in 1999, 11 additional wells were sampled. These were located just outside the exclusion boundary and belonged to local residents. Results are not presented here but are within the range of the results in Table 4.07.

Table 4.07
Well Water
(Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
ALPHA (22)	5.9E-002 (1.9E-002 -1.8E-001)	1.7E-001 (15/20) (3.3E-002 -5.1E-001)	N01	5.1E-001 (2/2) (5.1E-001 -5.1E-001)	6.0E-002 (1/2) (6.0E-002 -6.0E-002)
BETA (22)	3.9E-002 (2.3E-002 -1.0E-001)	1.2E-001 (18/20) (3.2E-002 -2.1E-001)	H04	2.1E-001 (1/2) (2.1E-001 -2.1E-001)	6.4E-002 (2/2) (5.5E-002 -7.3E-002)
H-3 (22)	1.3E+001 (1.2E+001 -1.4E+001)	2.4E+001 (7/20) (1.4E+001 -3.8E+001)	H04	3.5E+001 (2/2) (3.2E+001 -3.8E+001)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

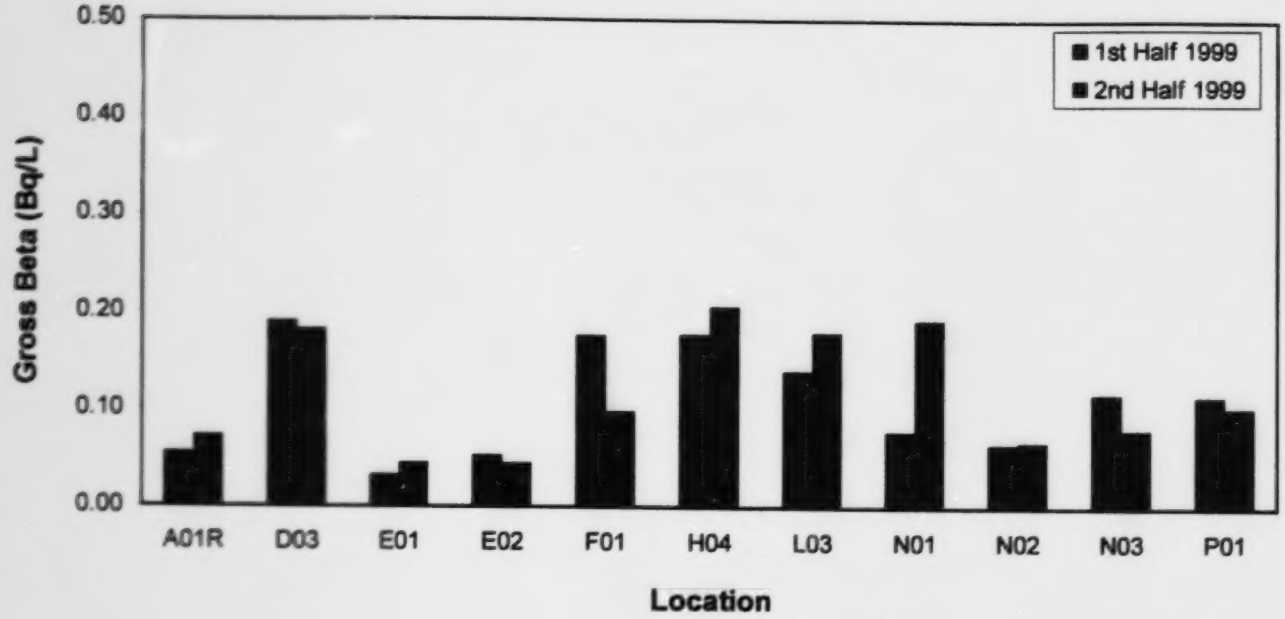

Figure 4.06
Gross Beta in Well Water

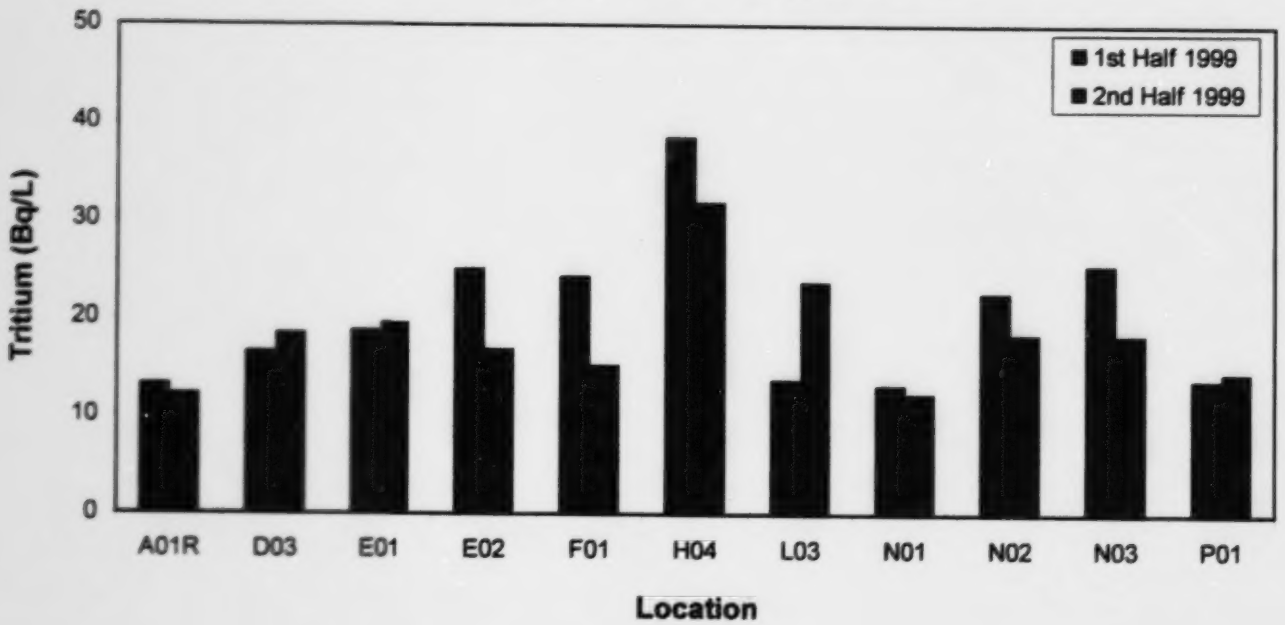

Figure 4.07
Tritium in Well Water

4.9 Pond/Puddle/Surface Water

Tritium, from PLGS emissions, was detected in 13 of the 18 samples. No other radionuclides were detected.

This category includes ponds, lakes, streams, and runoff samples. Most of these samples are from onsite locations.

Table 4.08 is a summary of the detected radionuclides in surface water. Detected H-3 activity ranged from 30 to 380 Bq/L. Variability can be due to the size of the reservoir and the residence time at the location. Figure 4.08 shows each sample (location codes are given in Appendix C). "Less Than" values are plotted for non-detected results.

Table 4.08
Pond/Puddle/Surface Water
(Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (18)	1.4E+001 (1.2E+001 -1.6E+001)	8.3E+001 (13/18) (3.0E+001 -3.8E+002)	I00	1.6E+002 (3/3) (4.3E+001 -3.8E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

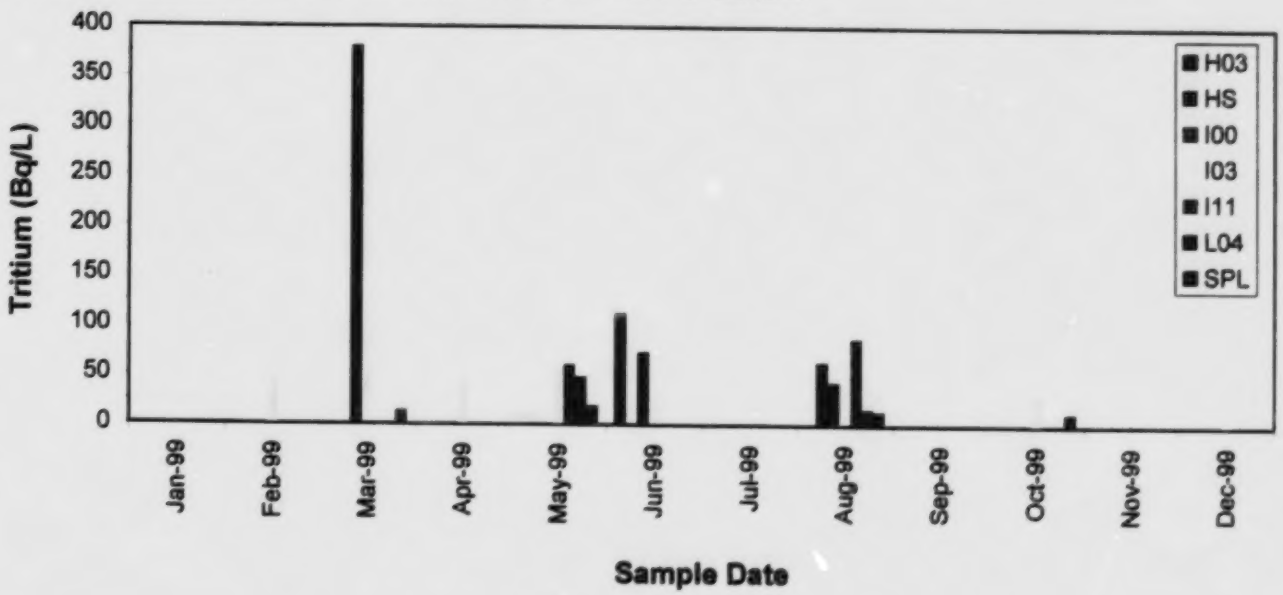

Figure 4.08
Tritium in Pond/Puddle/Surface Water

4.10 Berries

No radionuclides attributable to PLGS emissions were detected in these 12 samples.

Most of these samples were blueberries from the commercial fields at Pennfield. Some local residents provided other species from the Lepreau Peninsula.

It is not unusual to detect Cs-137 in berries throughout North America, although none was seen this year. As in many food samples, naturally occurring K-40 was detected in two samples (see Table 4.09).

Table 4.09
Berry, Various
(Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (7)	3.7E+001 (6.5E+000 -7.4E+001)	3.5E+001 (2/7) (3.1E+001 -4.0E+001)	B10	3.5E+001 (2/4) (3.1E+001 -4.0E+001)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.11 Garden Vegetables

No radionuclides attributable to PLGS emissions were detected in these 33 samples.

Most samples were taken from a local garden in Dipper Harbour (4 km away from PLGS in the predominant wind direction).

As in most food samples, naturally occurring K-40 was detected in 30 samples (see Table 4.10).

Table 4.10
Garden Vegetables
(Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (33)	4.1E+001 (1.3E+000 -1.5E+002)	1.3E+002 (30/33) (3.5E+001 -2.3E+002)	N01	1.3E+002 (30/33) (3.5E+001 -2.3E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level)..

F : Number of analyses greater than the Critical Level/Total number of analyses

4.12 Vegetation (Lichen)

No radionuclides from PLGS were detected in these 17 samples.

Different species of lichen and moss concentrate a wide range of radionuclides, both natural (Be-7 and K-40) and man-made (Cs-137), and are sensitive indicators of radionuclides in the environment. These samples are collected whenever and wherever available from onsite locations.

Only natural Be-7 and K-40 were detected in several of these samples in 1999 (Table 4.11).

Table 4.11
Vegetation
(Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Be-7 (17)	7.7E+001 (6.5E+000 -2.6E+002)	3.1E+002 (14/17) (1.4E+002 -5.5E+002)	L03	5.1E+002 (1/1) (5.1E+002 -5.1E+002)	*
K-40 (17)	2.7E+002 (5.3E+000 -4.2E+002)	1.7E+002 (2/17) (1.4E+002 -2.1E+002)	M05	2.1E+002 (1/4) (2.1E+002 -2.1E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.13 Soil

In 1999, there were no detectable radionuclides that could be attributed to the operation of PLGS in any of the eight samples analysed.

Soil samples are taken from a variety of onsite locations throughout most of the year.

Most samples contained naturally occurring K-40 (240 to 550 Bq/kg), Be-7 (48 to 68 Bq/kg) and Ac-228 (17 to 37 Bq/kg). Six contained Cs-137 (10 to 160 Bq/kg) at typical levels for the region. (see Table 4.12). Figure 4.09 shows individual Cs-137 results which seem to be a function of the organic load in the sample. "Less Than" values are plotted for non-detected results. Location codes are shown in Appendix C.

Table 4.12
Soil (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Be-7 (8)	1.9E+001 (3.8E+000 -4.0E+001)	6.1E+001 (3/8) (4.8E+001 -6.8E+001)	I00	6.7E+001 (2/3) (6.7E+001 -6.8E+001)	*
Cs-137 (8)	2.3E+000 (8.9E-001 -7.7E+000)	6.5E+001 (6/8) (1.0E+001 -1.6E+002)	I00	9.9E+001 (3/3) (4.0E+001 -1.6E+002)	*
Ac-228 (8)	6.3E+000 (2.6E+000 -1.9E+001)	2.6E+001 (6/8) (1.7E+001 -3.7E+001)	I03	3.6E+001 (1/2) (3.6E+001 -3.6E+001)	*
K-40 (8)	5.9E+001 (5.9E+000 -1.3E+002)	4.0E+002 (7/8) (2.4E+002 -5.5E+002)	I03	5.5E+002 (1/2) (5.5E+002 -5.5E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

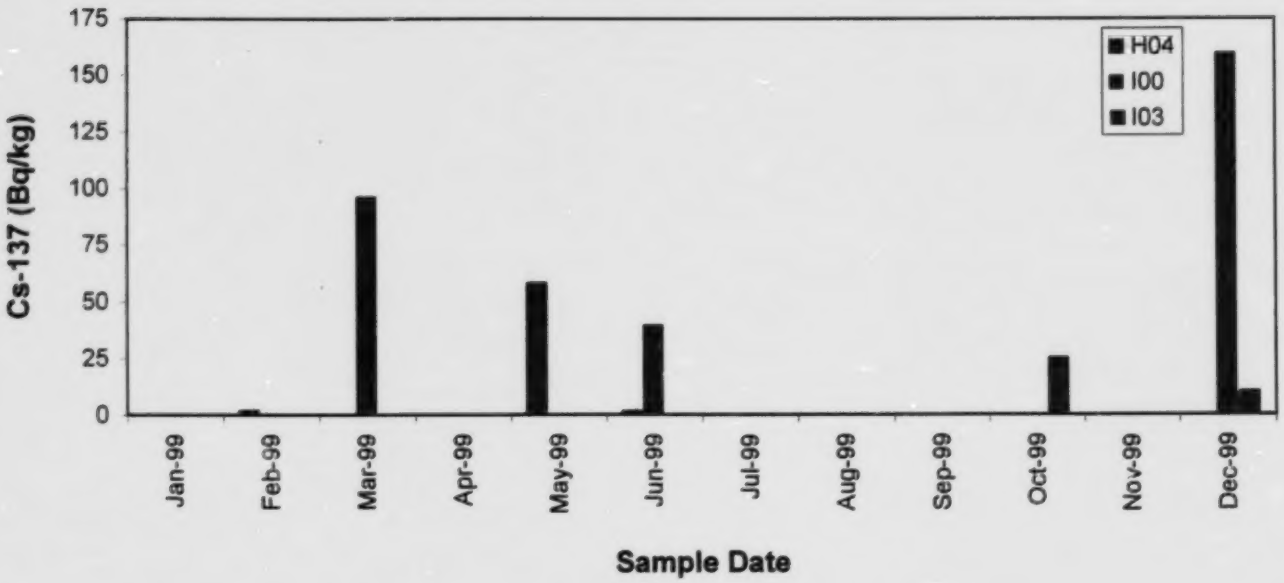

Figure 4.09
Cs-137 in Soil

4.14 Precipitation

Tritium from PLGS was detected in 36 of 44 onsite samples.

Rainwater is collected continuously at the four onsite air monitoring stations (shown in Figure 3.02). The samples are changed at least monthly, depending on rainfall and freeze up.

Detected H-3 levels spanned 12 to 220 Bq/L, depending on the amount of rainfall. Results are given in Table 4.13 and shown in Figure 4.10. "Less Than" values are plotted for non-detected results.

Table 4.13
Precipitation
(Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (44)	1.3E+001 (1.2E+001 -1.4E+001)	8.4E+001 (36/44) (1.2E+001 -2.2E+002)	H04	1.1E+002 (10/11) (5.1E+001 -2.2E+002)	*
Be-7 (44)	3.2E+000 (1.0E+000 -4.6E+000)	2.3E+000 (1/44) (2.3E+000 -2.3E+000)	L04	2.3E+000 (1/11) (2.3E+000 -2.3E+000)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

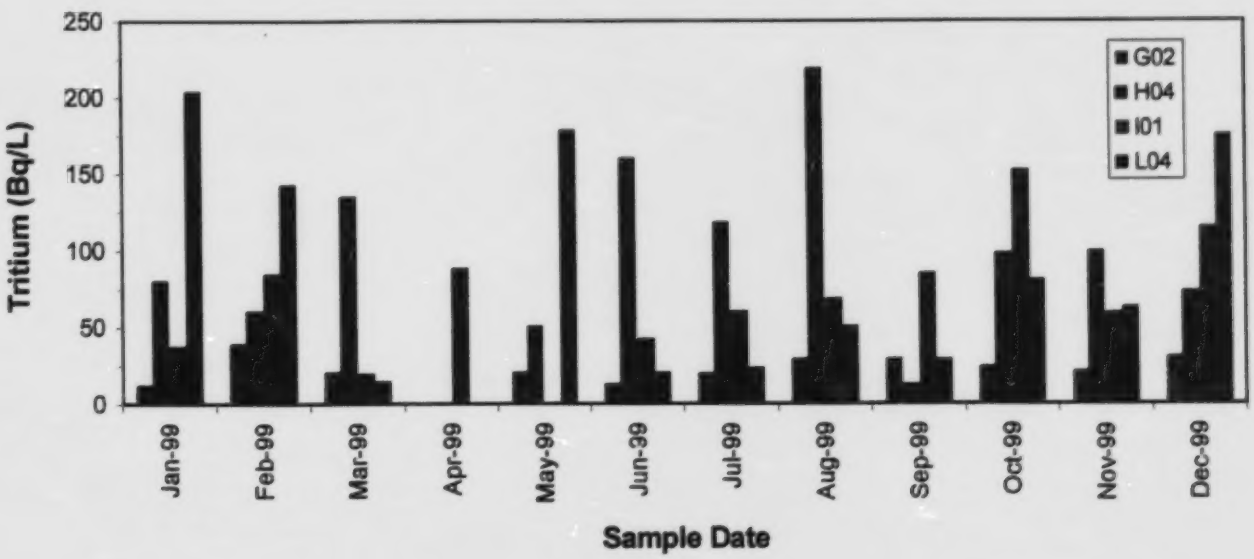

Figure 4.10
Tritium in Precipitation

4.15 Seawater

In 1999, there were no detectable radionuclides that could be attributed to the operation of PLGS in any of the 22 samples analysed.

Seawater is collected quarterly from three locations close to PLGS and one reference location near Saint John (shown in Figure 3.05). There are at least four samples for each of the locations except C01, which is not a routine site.

In past years, H-3 from PLGS and K-40 from nature have been detected. As seen in Table 4.14, the only radionuclide detected in 1999 is K-40. The Critical Level for H-3 in seawater averages about 12 Bq/L. Calculations suggest that the long term average concentration of tritium in seawater due to releases from PLGS in the liquid effluent pathway was about 70 Bq/L at the out-fall (samples are not usually collected at this point, but are taken at the shoreline nearby). This calculation takes into account the total tritium released over the year, the flow rate of the condenser cooling water (about 24 m^3/s), and tidal mixing. A dilution factor of 20 is assumed for tidal mixing at the out-fall during normal coolant flows. For collection further away, a tidal mixing factor of about 40 or even higher, is more realistic. A factor of 40 would result in an average of about 11 Bq/L of seawater in 1999 at the H03 location.

Table 4.14
Seawater
(Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (22)	3.0E+000 (9.9E-001 -6.4E+000)	1.1E+001 (18/18) (7.6E+000 -1.4E+001)	H05	1.2E+001 (8/8) (7.6E+000 -1.4E+001)	1.2E+001 (4/4) (1.1E+001 -1.4E+001)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.16 Clams

Most of the seafood analysed in the environmental program contain detectable levels of K-40 (see Table 4.15). No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999.

The nature of the fishery has changed over the last few years. The inshore fishery often faces restrictions placed upon the harvesting of shellfish, either for conservation of stocks or because of bacterial contamination, algal blooms, or other natural cycles. This restricts the availability of some sample types for analysis. Sample locations are shown in Figure 3.05.

Table 4.15
Clams
Edible, Raw Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (14)	7.6E+001 (2.2E+001 -1.4E+002)	1.8E+002 (10/12) (1.5E+002 -2.3E+002)	D04	2.0E+002 (5/6) (1.6E+002 -2.3E+002)	1.4E+002 (2/2) (1.1E+002 -1.8E+002)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.17 Fish

No samples were available for analyses in 1999. The nature of the fishery has changed over the last few years. Herring and mackerel, which used to make up the bulk of the analyses, are now less available for analysis. The fish category now tends to be made up of dogfish, cod, hake and sardines, if they are available at all.

4.18 Lobster

Most of the seafood analysed in the environmental program contain detectable levels of K-40 (see Table 4.16). No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999, even though several of the samples were collected close to the cooling water outflow from PLGS (Figure 3.05).

Table 4.16
Lobster
Edible, Cooked Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (8)	3.7E+001 (9.2E+000 -6.1E+001)	1.0E+002 (6/7) (6.6E+001 -1.2E+002)	H02	1.0E+002 (6/7) (6.6E+001 -1.2E+002)	5.9E+001 (1/1) (5.9E+001 -5.9E+001)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.19 Periwinkles

Most of the seafood analysed in the environmental program contain detectable levels of K-40 (see Table 4.17). No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999. Sample locations are shown in Figure 3.05.

Table 4.17
Periwinkles
Edible, Raw Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (14)	4.6E+001 (1.5E+001 -1.4E+002)	1.2E+002 (13/14) (8.4E+001 -1.5E+002)	E03	1.3E+002 (5/5) (1.1E+002 -1.5E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.20 Aquaculture Salmon

The aquaculture salmon industry is important to the area west of PLGS. Potassium-40 is detected in all of these samples (see Table 4.18). As liquid emissions from PLGS are monitored continuously, and were insignificant all year, no radionuclides attributable to the operation of PLGS would be expected to be detected in these remote samples.

Table 4.18
Aquaculture Salmon
Raw Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (3)	2.8E+001 (3.0E+000 -4.6E+001)	1.5E+002 (2/2) (1.4E+002 -1.7E+002)	A08	1.5E+002 (2/2) (1.4E+002 -1.7E+002)	1.9E+002 (1/1) (1.9E+002 -1.9E+002)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.21 Scallops

Most of the seafood analysed in the environmental program contain detectable levels of K-40 (see Table 4.19). Scallops may also contain detectable quantities of Ac-228. No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999.

The inshore fishery often faces restrictions or total bans placed upon the harvesting of scallops for conservation of stocks. This affects the number of samples available for analysis.

Table 4.19
Scallops
Edible, Raw Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (3)	2.4E+001 (3.1E+000 -6.3E+001)	1.2E+002 (3/3) (7.5E+001 -1.9E+002)	H02	1.5E+002 (2/2) (1.1E+002 -1.9E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.22 Crab

As with other seafood, K-40 was the only radionuclide detected in these samples (see Table 4.20). There was no active crab fishery in the local area and there were no samples available other than these reference samples.

Table 4.20
Crab
Edible, Raw Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (2)	3.0E+001 (2.8E+001 -3.2E+001)	*		*	5.4E+002 (2/2) (5.2E+002 -5.6E+002)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.23 Dulse

Most of the seafood analysed in the environmental program contain detectable levels of K-40. No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999 (see Table 4.21).

Dulse is an edible seaweed that is a popular snack food in the area. Seven samples were collected in 1999 at locations shown in Figure 3.05.

Table 4.21
Dulse
Wet Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
K-40 (7)	9.1E+001 (1.9E+001 -1.6E+002)	4.7E+002 (7/7) (1.7E+002 -1.0E+003)	N05	1.0E+003 (1/1) (1.0E+003 -1.0E+003)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.24 Other Sea Plants

Most of the seafood analysed in the environmental program contain K-40. No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999.

Sea plants other than dulse are analysed. Various species of seaweed (for example, *Ascophylum*) occur on the rocks on the Point Lepreau peninsula and are collected from time to time. One of the 15 samples collected contained Be-7, a cosmogenic radionuclide. All contained naturally occurring K-40 at an average of 200 Bq/kg (see Table 4.22).

Table 4.22
Sea Plant
Wet Mass (Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Be-7 (15)	6.0E+000 (3.4E+000 -9.2E+000)	*		*	1.3E+001 (1/4) (1.3E+001 -1.3E+001)
K-40 (15)	3.1E+001 (2.3E+000 -5.0E+001)	2.0E+002 (11/11) (1.5E+002 -2.8E+002)	E03	2.0E+002 (6/6) (1.6E+002 -2.3E+002)	2.0E+002 (4/4) (1.7E+002 -2.5E+002)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.25 Sediment

No contribution of gamma emitting radionuclides from the operation of Point Lepreau was detected in 1999.

Sediments are collected quarterly from ten locations (shown in Figure 3.05). All samples contain radioactivity from naturally occurring radionuclides (K-40 from the natural potassium in feldspar, a common mineral) and from the diminishing levels of Cs-137 fallout from bomb tests since the 1950s. A small additional Cs-137 component from Chernobyl was added to this reservoir in 1986. Actinium-228 (radioactive progeny of naturally occurring Th-232), and Be-7 (of cosmogenic origin) commonly occur in sediments. Finer grain sediments have a higher radioactivity content than coarse sediments.

See Table 4.23 for a summary of the data. Figure 4.11 shows the Cs-137 concentration for each location. "Less Than" values are plotted for non-detected results. Location codes are listed in Appendix C

Table 4.23
Sediment
(Bq/kg)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Be-7 (40)	8.1E+000 (3.5E+000 -1.4E+001)	4.5E+001 (18/36) (1.6E+001 -1.2E+002)	N04	7.5E+001 (4/4) (3.4E+001 -1.2E+002)	5.1E+001 (4/4) (3.0E+001 -8.7E+001)
Cs-137 (40)	1.4E+000 (5.1E-001 -3.3E+000)	4.0E+000 (4/36) (3.1E+000 -4.5E+000)	N04	4.5E+000 (1/4) (4.5E+000 -4.5E+000)	2.6E+000 (2/4) (2.4E+000 -2.8E+000)
Ac-228 (40)	3.0E+000 (1.5E+000 -5.0E+000)	2.6E+001 (26/36) (1.1E+001 -6.3E+001)	N04	4.0E+001 (4/4) (2.5E+001 -6.3E+001)	3.5E+001 (4/4) (2.4E+001 -4.2E+001)
K-40 (40)	6.0E+001 (2.9E+000 -1.6E+002)	5.6E+002 (36/36) (4.2E+002 -8.0E+002)	N04	7.0E+002 (4/4) (6.0E+002 -8.0E+002)	5.3E+002 (4/4) (4.7E+002 -6.4E+002)

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

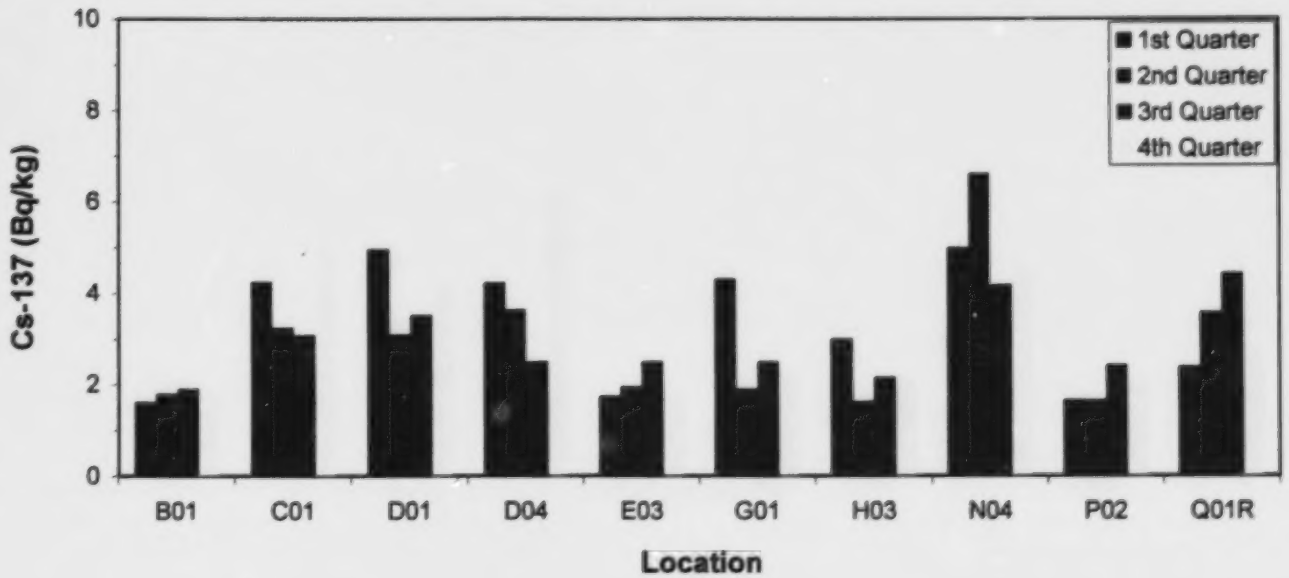

Figure 4.11
Cs-137 in Sediment

4.26 Gamma Surveys (Beaches)

Environmental gamma survey measurements are made in the inter-tidal zone on beaches in the Point Lepreau area and at the reference location 28 km to the east northeast (Figure 3.05). Although TLDs are preferred in measuring such exposures since they span the entire year and provide integrated measurements, they cannot be used in these locations. Radiation values measured in 1999 were consistent with those measured prior to station start-up in 1982. These are summarised in Table 4.24

Table 4.24
Beach Surveys- Inter-tidal Zone
Ion Chamber (μSv/h) *

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4
B01	0.17	0.17	0.35	0.20
C01	0.16	0.14	0.17	0.10
D01	0.19	0.13	0.10	0.13
D04	0.15	0.14	0.15	0.23
E03	0.16	0.15	0.18	0.23
G01	0.20	0.22	0.13	0.25
H03	0.19	0.22	0.24	0.19
H04	0.22	0.13	0.19	0.19
P02	0.18	0.15	0.22	0.17
G01R	0.19	0.19	0.19	0.12

* : Although two decimal places are quoted, none of the determinations has this degree of precision nor of accuracy. The data are quoted to two figures just as they are estimated at each location. They should be regarded as about 0.1 to 0.2 uSv/h.

NA : Data not Available

4.27 Liquid Radiostrontiums (LEM)

Since Sr-89,90 releases are so low, the expected concentration in environmental samples is well below the detection limit.

PLGS liquid emissions are measured by the Liquid Effluent Monitor (LEM) before their release. A monthly composite is sent to the lab for analyses. Twelve of these composites were analysed for Sr-89,90. If the release rate warrants a Sr-89,90 analysis is performed on seawater samples.

Strontium-90 was detected in several of these LEM samples at a level close to the detection limit. This translated into 1.1E+06 Bq released in 1999, compared with an annual DEL of 1.8E+14 Bq. No further analyses were indicated. See Figure 4.12.

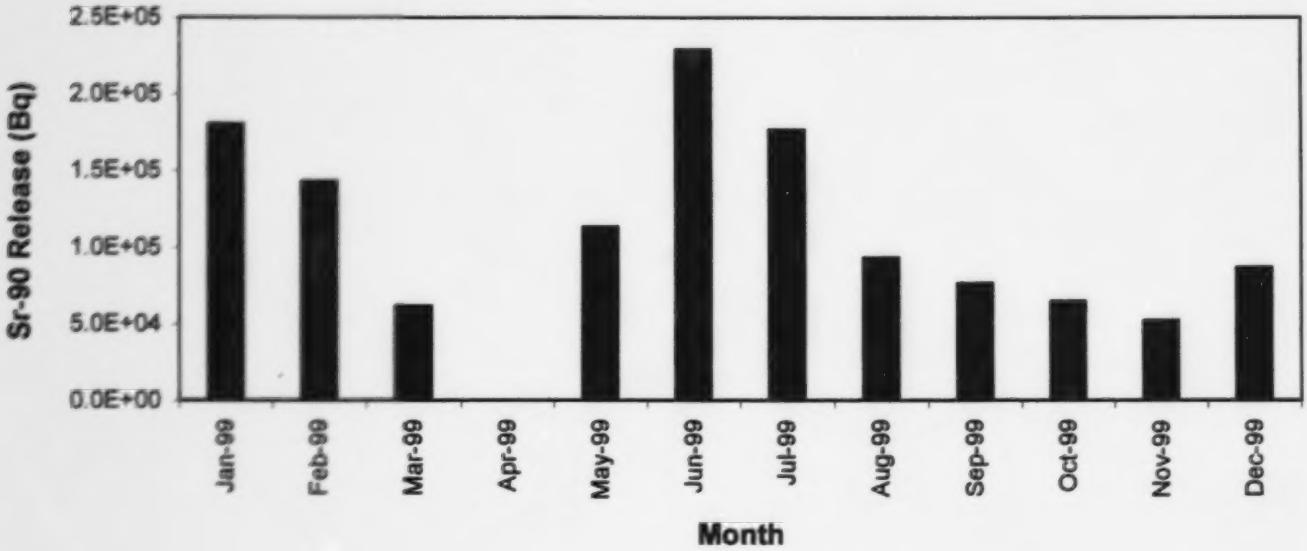

Figure 4.12
Sr-90 Releases (measured at source)

4.28 Bore Hole Water (SRWMF)

Tritium from PLGS was detected in the 60 samples analysed. No other radionuclides attributable to the operation of PLGS were detected.

Water from bore holes on the SRWMF site (Phase 1 and 2) are collected each quarter (a total of 68 samples, if all contain sufficient water to be sampled).

Tritium concentrations averaged 94 Bq/L, ranging up to 350 Bq/L. Most near-surface groundwater in the area is from rainfall which may contain up to this concentration, or more. Contamination of some of the bore holes by surface runoff is unavoidable when the bore holes are first opened because of standing-water covering the well cap. See Tables 4.25 and 4.26. Figure 4.13 shows the H-3 at each bore hole for each sample. Locations I00A and I00B are the closest to the SRWMF-Phase 1 structures and may be affected by the higher H-3 levels associated with them. "Less Than" values are plotted for non-detected results.

Table 4.25
Bore Hole Water
SRWMF - Phase 1 (Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (12)	1.3E+001 (1.2E+001 -1.5E+001)	2.0E+002 (12/12) (4.0E+001 -3.5E+002)	I00B	3.3E+002 (4/4) (3.1E+002 -3.5E+002)	*
Be-7 (12)	1.1E+000 (8.5E-001 -1.5E+000)	3.3E+000 (1/12) (3.3E+000 -3.3E+000)	I00A	3.3E+000 (1/4) (3.3E+000 -3.3E+000)	*
K-40 (12)	2.6E+000 (8.7E-001 -3.3E+000)	3.5E+000 (1/12) (3.5E+000 -3.5E+000)	I00A	3.5E+000 (1/4) (3.5E+000 -3.5E+000)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

Table 4.26
Bore Hole Water
SRWMF - Phase 2 (Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (48)	1.3E+001 (1.2E+001 -1.5E+001)	6.7E+001 (48/48) (2.7E+001 -2.1E+002)	I03B	1.5E+002 (4/4) (1.2E+002 -2.1E+002)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

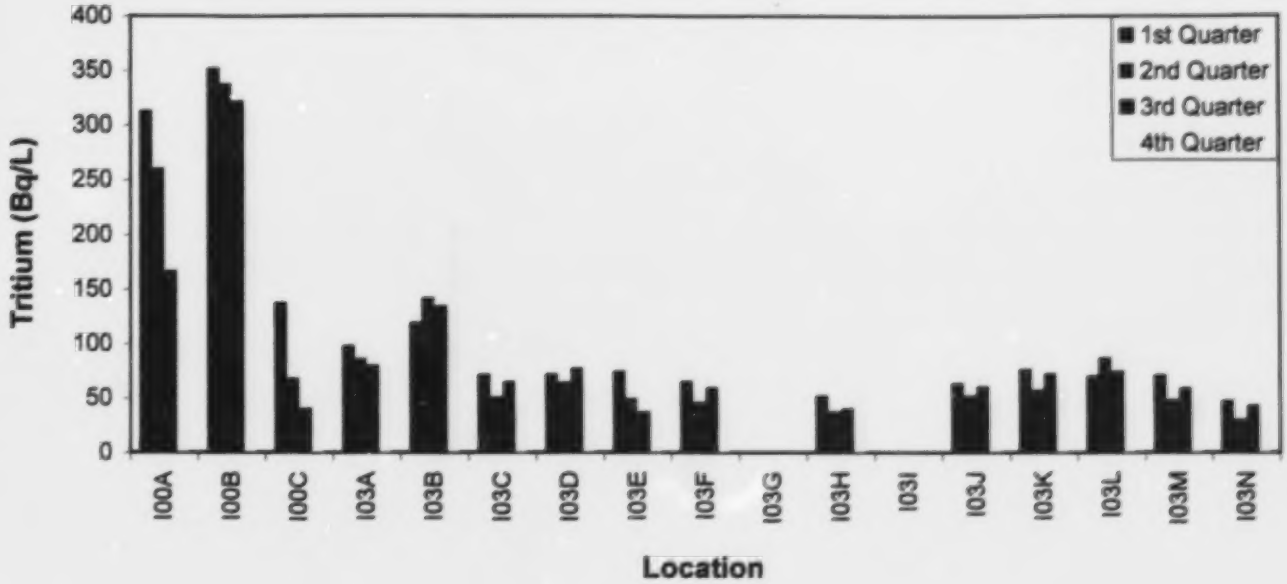

Figure 4.13
Tritium in Bore Holes

4.29 Parshall Flume (SRWMF)

Tritium from PLGS was detected in 105 of 106 samples reaching 1.2E+04 Bq/L, with a mean value of about 6.6E+02 Bq/L. No other radionuclides attributable to the operation of PLGS were detected.

Rainwater at the SRWMF (Phase 1 and 2) is obtained from drainage channels (flumes) constructed to collect surface runoff from these areas. Samples are collected and analysed on a weekly basis. There is little or no flow into or out of these collection locations during the winter months and values for H-3 tend to vary little from one week to the next except after heavy rain. The values at Phase 2 are typically less than those at Phase 1, indicating possible groundwater dilution of the surface runoff to the flume or a developing problem with the Phase 1 structures. See Tables 4.27 and 4.28. Figure 4.14 compares the H-3 in the samples from the two facilities.

Table 4.27
Parshall Flume
SRWMF - Phase 1 (Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Highest Indicator Station Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (53)	1.3E+001 (1.1E+001 -2.1E+001)	1.3E+003 (53/53) (2.7E+002 -1.2E+004)	IO1	1.3E+003 (53/53) (2.7E+002 -1.2E+004)	*

* : The activity is less than or equal to the Critical Level (95% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

Table 4.28
Parshall Flume
SRWMF - Phase 2 (Bq/L)

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Highest Indicator Station Mean (F) (Range)	Reference Station Mean (F) (Range)
H-3 (53)	1.3E+001 (1.1E+001 -1.5E+001)	5.9E+001 (52/53) (2.1E+001 -1.4E+002)	IO2	5.9E+001 (52/53) (2.1E+001 -1.4E+002)	*

* : The activity is less than or equal to the Critical Level (95% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

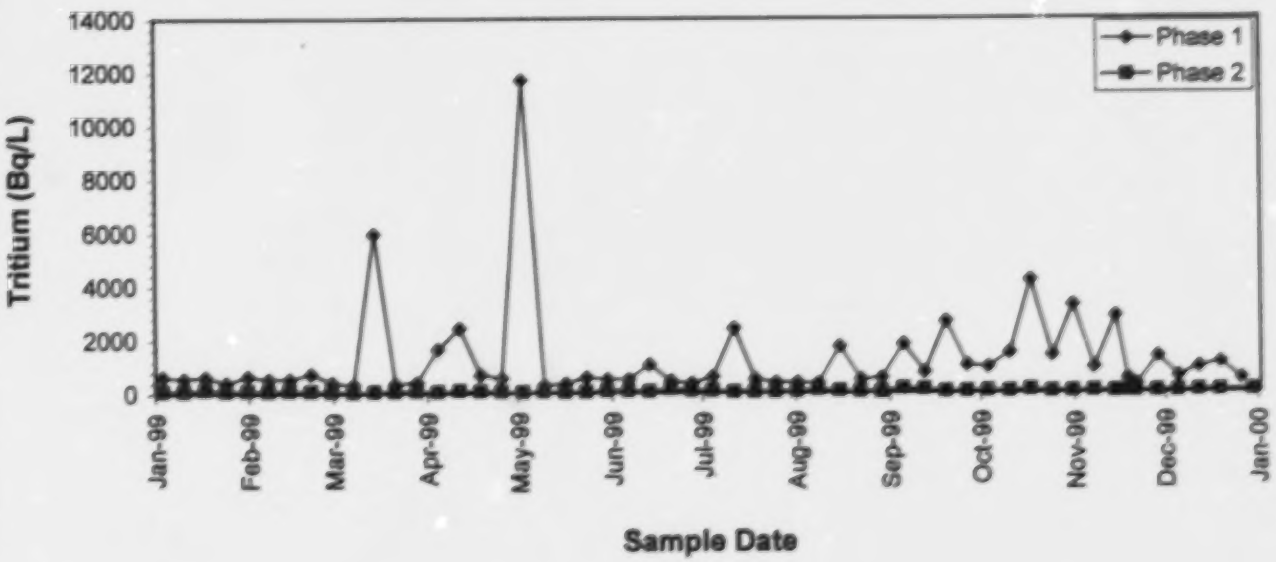

Figure 4.14
Tritium in Parshall Flumes

4.30 Drop-off TLDs (SRWMF - Phase 2)

The measured radiation decreases as the distance from the SRWMF - Phase 2 increases.

Dosimeters are placed in two directions from the boundary fence of Phase 2 to measure drop-off of radiation with distance from the filled dry fuel storage canisters, to about 200 metres. Results are presented in Table 4.29.

There were 82 concrete canisters filled to the end of 1999 with 44 081 used-fuel bundles. Radiation drop-off measurements (Figure 4.15) with increasing distance away from the fence show distinct differences. The 'A' direction (mostly swamp after 20 m from the fence) covers drop-off to the north-east away from the perimeter fence. The 'B' direction (mostly rock with some shallow sandy overburden) covers drop-off to the north-west away from the perimeter (after 75 m the TLDs are shielded from the facility by the high ground).

Table 4.29
TLD, Drop-off
(μGy)

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
A 5m	218 +- 22	208 +- 21	229 +- 23	245 +- 24	900 +- 50
A 10m	213 +- 21	217 +- 22	213 +- 21	235 +- 23	880 +- 40
A 15m	170 +- 17	178 +- 18	183 +- 18	201 +- 20	730 +- 40
A 20m	111 +- 11	130 +- 13	119 +- 12	147 +- 15	510 +- 30
A 25m	105 +- 10	111 +- 11	107 +- 11	133 +- 13	450 +- 20
A 50m	90 +- 9	100 +- 10	93 +- 9	121 +- 12	400 +- 20
A 75m	92 +- 9	108 +- 11	95 +- 10	122 +- 12	420 +- 20
A 100m	78 +- 8	87 +- 9	81 +- 8	110 +- 11	360 +- 20
A 118m	107 +- 11	118 +- 12	121 +- 12	142 +- 14	490 +- 20
B 5m	261 +- 26	265 +- 27	284 +- 28	289 +- 29	1100 +- 60
B 10m	231 +- 23	237 +- 24	254 +- 25	274 +- 27	1000 +- 50
B 15m	192 +- 19	216 +- 22	221 +- 22	241 +- 24	870 +- 40
B 20m	194 +- 19	217 +- 22	237 +- 24	232 +- 23	880 +- 40
B 25m	179 +- 18	207 +- 21	214 +- 21	223 +- 22	820 +- 40
B 50m	154 +- 15	182 +- 18	179 +- 18	190 +- 19	700 +- 40
B 75m	149 +- 15	167 +- 17	170 +- 17	187 +- 19	670 +- 30
B 100m	183 +- 18	195 +- 19	195 +- 19	209 +- 21	780 +- 40
B 150m	158 +- 16	182 +- 18	165 +- 16	191 +- 19	700 +- 30
B 200m	165 +- 17	176 +- 18	180 +- 18	197 +- 20	720 +- 40

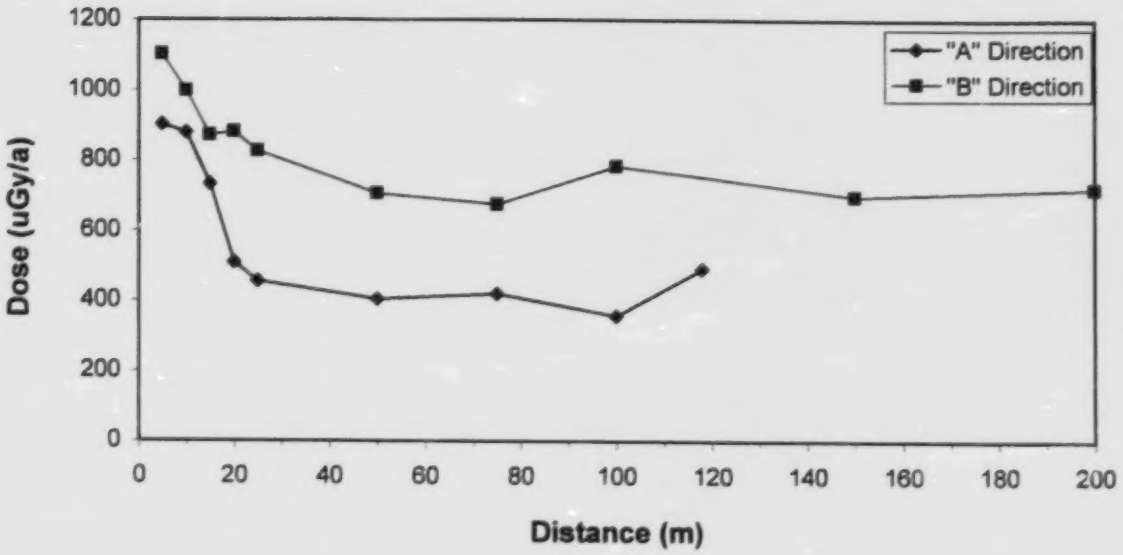

Figure 4.15
Drop-off TLDs

4.31 Hemlock Knoll Regional Sanitary Landfill

In December, 1999, PLGS began disposing of its non-active waste at the public landfill facility. A monitoring program was established prior to the first shipment. It includes sampling of water from the leachate, bore holes and various holding ponds; sampling of the soil and gamma surveys of the disposal cell surface; and dosimeter placement at key locations.

There were 123 water samples, 16 soil samples, 16 gamma meter measurements and 10 TLD results. Since most of these results apply to the time prior to the first waste shipment, they constitute a background study. Cesium-137 was detected in two of the 16 soil samples at levels similar to other soil samples. Table 4.30 summarises the gamma survey results and Table 4.31 summarises the soil sample results. There were no radionuclides detected in the water samples, other than naturally occurring isotopes which are not reported here. TLD results appear in Table 4.05 (location codes YTL1 to YTL5).

Table 4.30
Gamma Surveys - Hemlock Knoll Regional Sanitary Landfill
Ion Chamber (µSv/h) *

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4
YODC1	NA	NA	0.11	0.11
YODC2	NA	NA	0.12	0.11
YODC3	NA	NA	0.13	0.11
YODC4	NA	NA	0.13	0.11
YODC5	NA	NA	0.11	0.12
YODC6	NA	NA	0.10	0.10
YYW1	NA	NA	0.13	0.14
YYW2	NA	NA	0.14	0.10

* : Although two decimal places are quoted, none of the determinations has this degree of precision nor of accuracy. The data are quoted to two figures just as they are estimated at each location. They should be regarded as about 0.1 to 0.2 uSv/h.

NA : Data not Available

Table 4.31
Soil (Bq/kg)
Hemlock Knoll Regional Sanitary Landfill

Analysis Type (Total Number)	Critical Level Mean (Range)	Indicator Stations Mean (F) (Range)	Highest Indicator Station Location	Mean (F) (Range)	Reference Station Mean (F) (Range)
Cs-137 (16)	1.2E+000 (7.1E-001 -2.0E+000)	1.7E+000 (2/16) (8.9E-001 -2.4E+000)	YYW2	2.4E+000 (1/2) (2.4E+000 -2.4E+000)	*

* : The activity is less than or equal to the Critical Level (99% Confidence Level).

F : Number of analyses greater than the Critical Level/Total number of analyses.

4.32 Meteorological Data

A problem was discovered in the meteorological data for the years 1992 to 1999: the temperature reading from the 42 metre elevation (at the Point Lepreau Generating Station tower) contained a bias which affected the calculation of the Pasquill Stability factor.

The meteorological data for 1999, and a compilation of the available 1986 to 1999 data, have this information removed and are presented in Tables 4.32 and 4.33. Data were collected hourly. Wind Rose data for 1999 are presented in Figure 4.16 and a pie-plot of the average percentage frequency of Pasquill stability classes for the years from 1986 to 1991 in the Point Lepreau area is presented in Figure 4.17.

Table 4.32
Meteorological Data For Point Lepreau (1999)

	Temperature (Degrees Celsius) *10 Metre Tower data*					Wind direction (Relative %) *42 Metre Tower data*							
		Mean Daily		Extreme		%Observations from							
Month	Avg	Max	Min	Max	Min	N	NE	E	SE	S	SW	W	NW
January	-5.5	-0.8	-10.7	8.3	-25.0	18	11	7	3	7	15	25	14
February	-2.5	1.3	-6.0	8.0	-17.2	21	13	4	6	4	6	16	31
March	2.4	5.0	-0.3	13.2	-5.6	17	16	3	9	10	12	26	7
April	4.5	8.2	1.2	13.5	-4.1	18	6	2	8	12	13	18	23
May	9.6	13.8	6.2	20.7	0.4	10	17	6	12	20	17	14	5
June	12.6	16.8	9.8	28.1	6.6	3	11	5	12	30	28	7	4
July	15.1	18.9	12.4	24.8	10.3	2	15	6	9	23	28	11	5
August	15.7	19.4	13.0	25.8	10.4	13	8	3	8	19	25	15	10
September	15.1	18.0	12.5	24.2	7.1	6	13	7	17	23	18	11	7
October	8.1	11.3	4.4	14.8	-4.4	12	7	4	9	21	11	25	12
November	4.9	7.6	1.5	16.9	-6.1	9	5	9	10	8	18	27	14
December	-0.5	2.8	-4.0	10.9	-15.5	21	6	3	5	8	8	32	17
Means	6.4	10.0	3.1	28.1	-25.0	13	11	5	9	16	16	19	12
Years	1	1	1	1	1	1	1	1	1	1	1	1	1

*Each compass direction covers ±22.5 degrees

Table 4.33
Meteorological Data for Point Lepreau
(six year average 1986 to 1991)

	Temperature					Wind direction															
	Degrees Celsius					Relative %								Relative %							
		Mean Daily		Extreme		%Observations from								Pasquill Stability Classes							%
Month	Avg	Max	Min	Max	Min	N	NE	E	SE	S	SW	W	NW	A	B	C	D	E	F	G	UNAV
January	-4.9	-0.8	-8.9	7.2	-25.3	11	10	4	5	10	19	18	23	19	9	8	26	22	12	5	3
February	-5.4	-1.8	-9.4	7.3	-21.9	16	8	3	4	11	22	15	23	22	11	11	23	19	9	5	1
March	-1.5	1.5	-4.7	13.5	-24.9	19	13	4	5	15	17	9	19	16	8	8	25	25	12	7	2
April	3.3	5.9	1.1	16.4	-4.2	20	25	6	6	17	13	8	5	12	5	7	25	33	12	6	15
May	7.9	11.2	5.5	25.6	-0.7	13	19	6	6	22	22	7	5	8	4	6	21	32	17	13	18
June	11.4	14.6	9.0	26.1	4.1	8	17	7	6	20	23	12	8	4	2	3	16	36	23	16	14
July	14.4	17.3	12.0	25.2	6.9	5	12	5	7	25	31	10	6	2	1	2	11	31	27	27	9
August	14.8	17.5	12.7	25.0	8.3	6	10	5	8	23	27	14	8	2	1	1	9	29	33	26	7
September	12.0	14.4	9.9	26.3	1.1	8	9	4	6	20	24	16	14	5	2	3	18	34	25	13	6
October	8.4	10.7	6.1	18.9	-1.7	13	10	7	9	19	18	14	11	5	4	5	27	30	17	12	3
November	2.8	5.7	-0.2	14.5	-13.7	13	9	4	7	11	13	22	23	9	5	8	34	25	15	4	1
December	-4.0	-0.1	-8.0	11.1	-21.1	13	6	5	3	7	13	25	28	18	11	11	27	21	9	3	5
Means	4.9	8.1	2.2	26.3	-25.3	12	12	5	6	17	20	14	15	10	5	6	22	28	17	11	7
Years	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6

42 Metre Tower data

*Each compass direction covers ±22.5 degrees

UNAV: The percentage of time that the instrumentation was unavailable and could not record the weather.

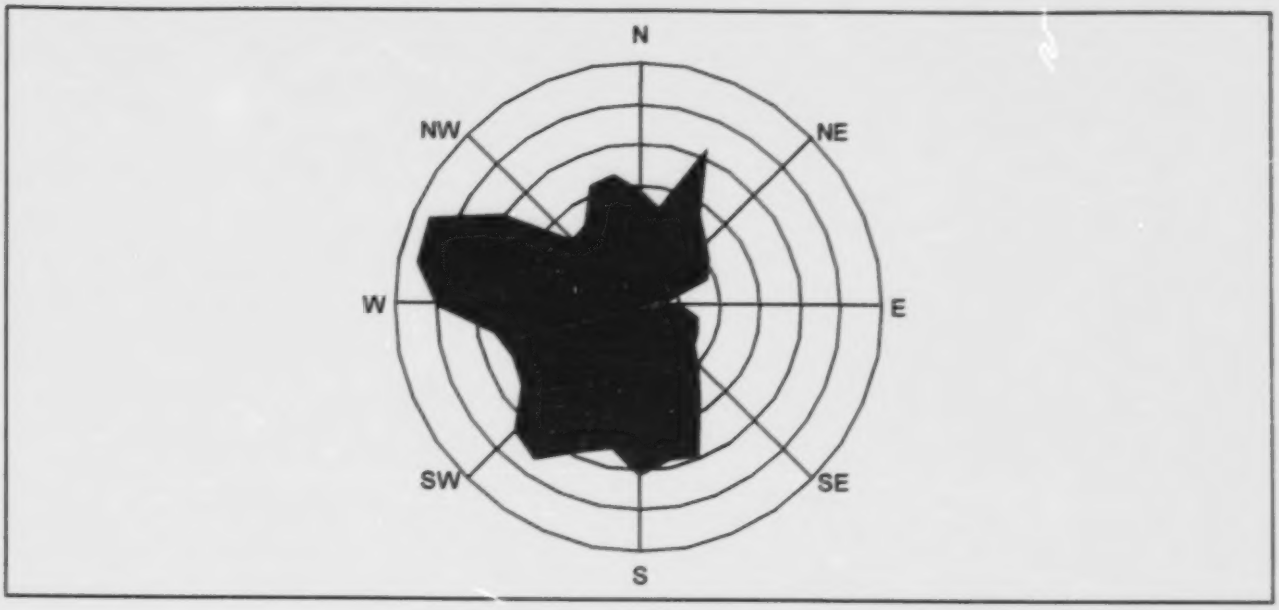

Figure 4.16
Wind Rose For Point Lepreau
(1999)

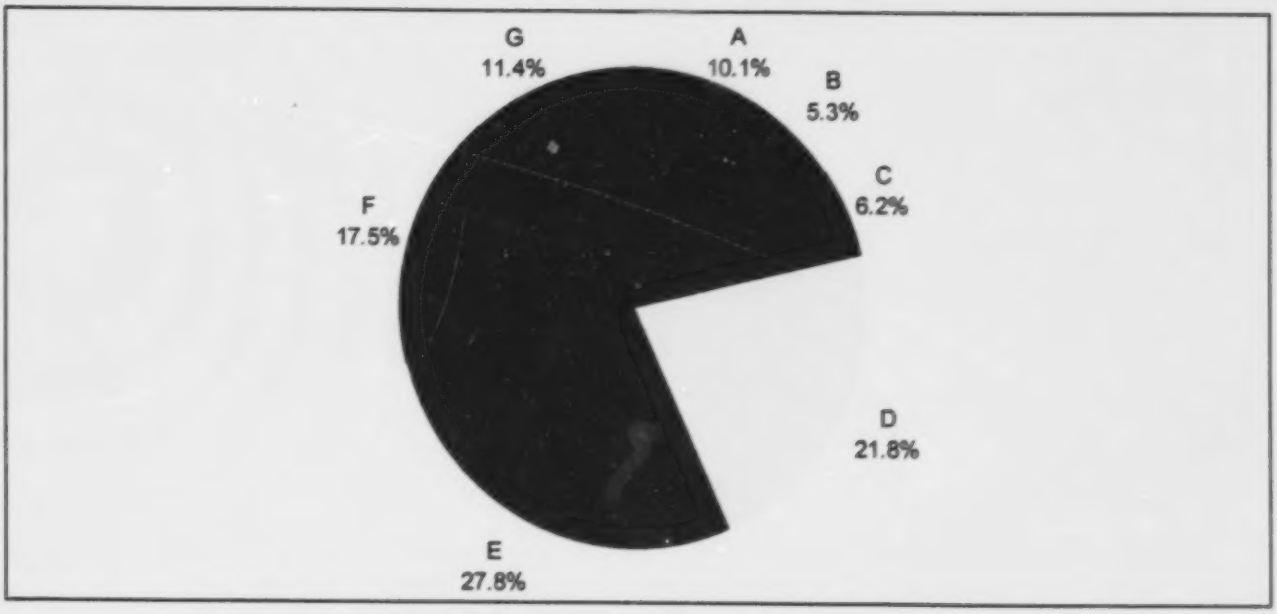

Figure 4.17
Pasquill Stability Factors For Point Lepreau
(1986 to 1991)

5.0 Trends

The only trends that were obvious from the historical data, and continued in 1999 were:

- decreasing H-3 in onsite air samples (Table 5.07)
- increasing H-3 in bore hole water from the SRWMF – Phase 1 (Table 5.16)
- increasing H-3 in Parshall Flume water from the SRWMF – Phase 1 (Table 5.20)

As in the figures in Section 4, "Less Than" values are plotted for non-detected values. All location codes are described in Appendix C.

Figure 5.01 Dose from Airborne and Liquid Pathways

Radiation dose from PLGS emissions continues to be well below the public dose limit (5000 microsieverts per annum), and also well below the operating target for nuclear power facilities in Canada (50 microsieverts per annum).

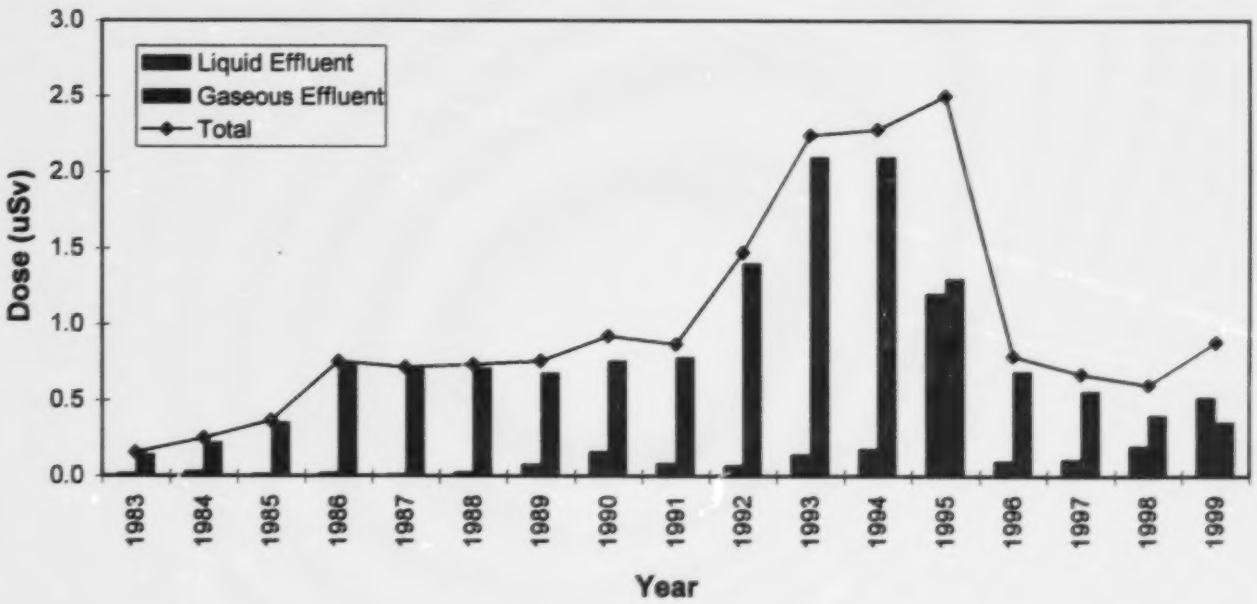

Figure 5.01
Dose from Airborne and Liquid Pathways

Figure 5.02 to Figure 5.05 Gross Beta in Air

Figures 5.02 and 5.03 show the gross beta data for all air stations since the NB Power program began in 1976. A plot of the gross beta data from Dipper Harbour, about 4 km from the PLGS stack and in the predominant downwind direction, is presented in Figure 5.04. The baseline data show the naturally occurring radioactivity in the area. The peaks on the plots correspond to fallout from various atmospheric bomb tests which were most common in the 1950s and 1960s but decreased into the 1970s. Fallout from the Chinese atmospheric bomb test in October of 1980 (fallout occurred in 1981 in N.B.), and from the Chernobyl accident in April 1986, were obvious. Figure 5.05 shows a comparable plot of data from Health and Welfare Canada, but for the whole of Canada from 1959 (when data were first collected) to 1991. The scale is very much condensed to allow the bomb test fallout levels to be kept on-scale.

The Chernobyl accident released, in a period of a few days, about 1% as much radioactivity to the environment as all of the U.S. atmospheric bomb tests combined, released over several years.

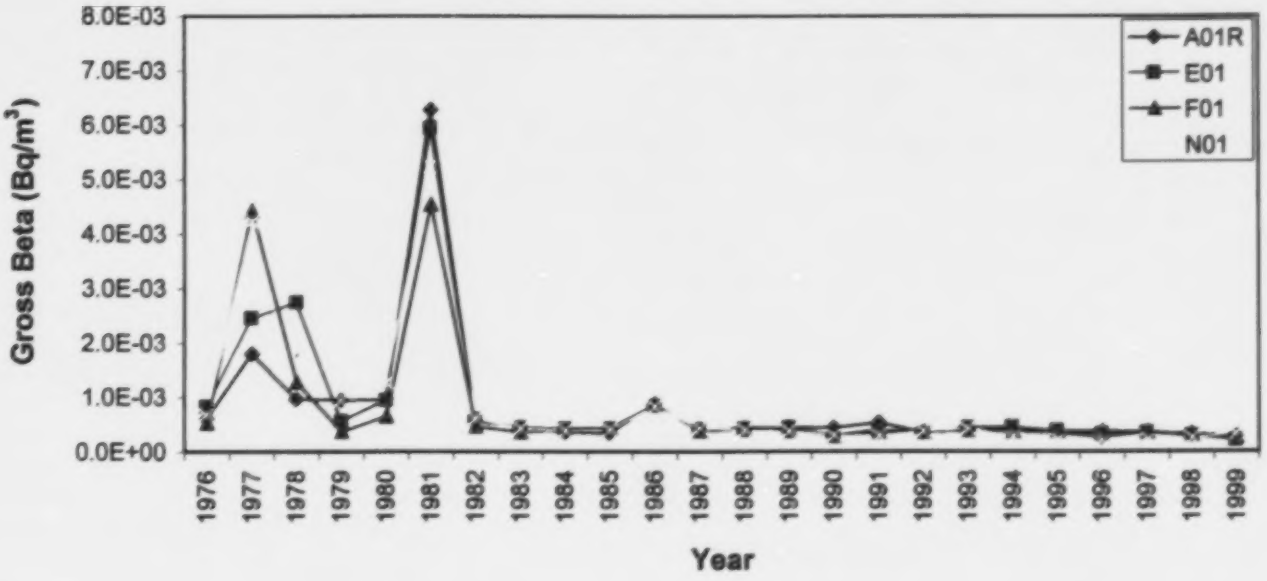

Figure 5.02
Gross Beta in Air (Offsite Air Stations)

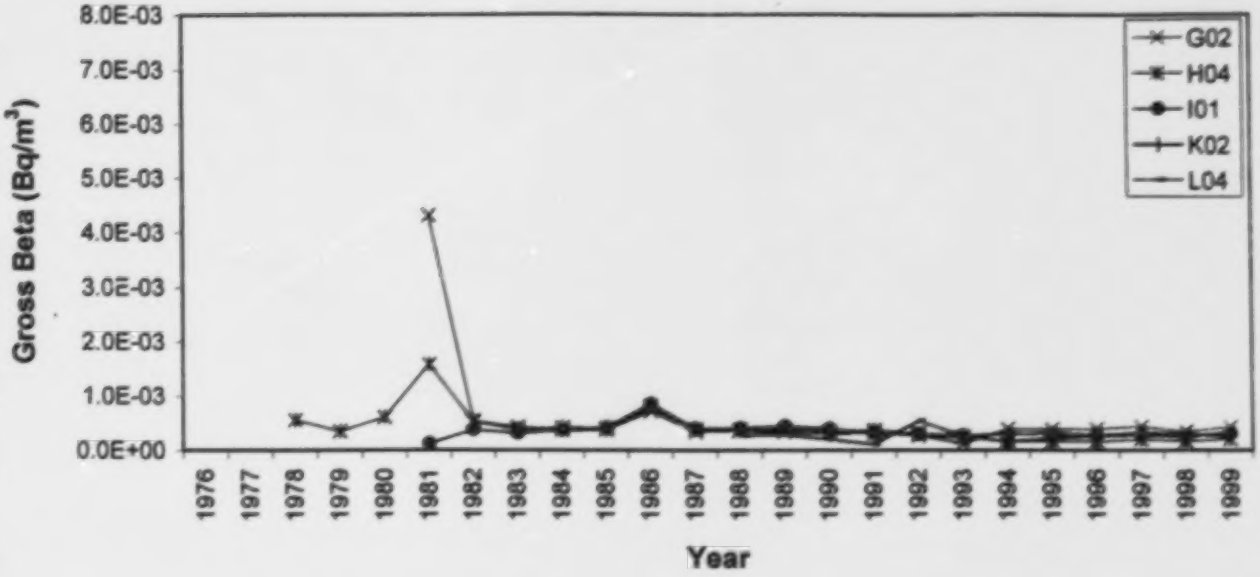

Figure 5.03
Gross Beta in Air (Onsite Air Stations)

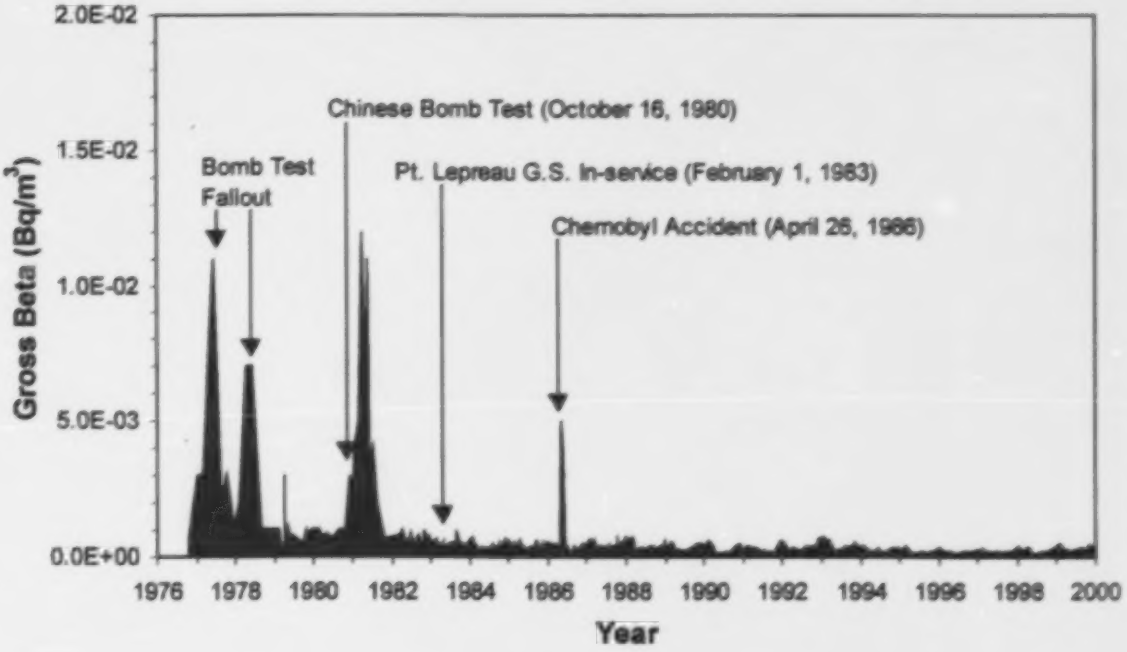

Figure 5.04
Gross Beta Activity in Air at Dipper Harbour

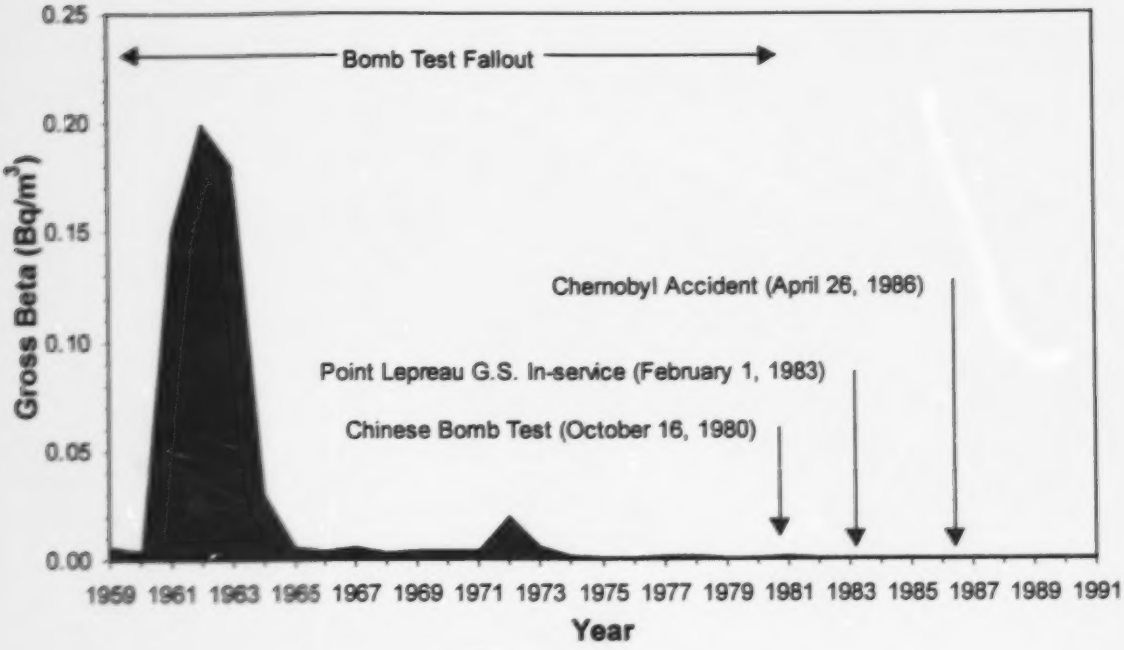

Figure 5.05
Annual Average Gross Beta Activity in Air for Canada
1959 to 1991 (Health and Welfare Canada Data)

Figure 5.06 and Figure 5.07 Tritiated Water in Air
The onsite stations show a decline since the peak in 1993/1994, as have station airborne tritium emissions.

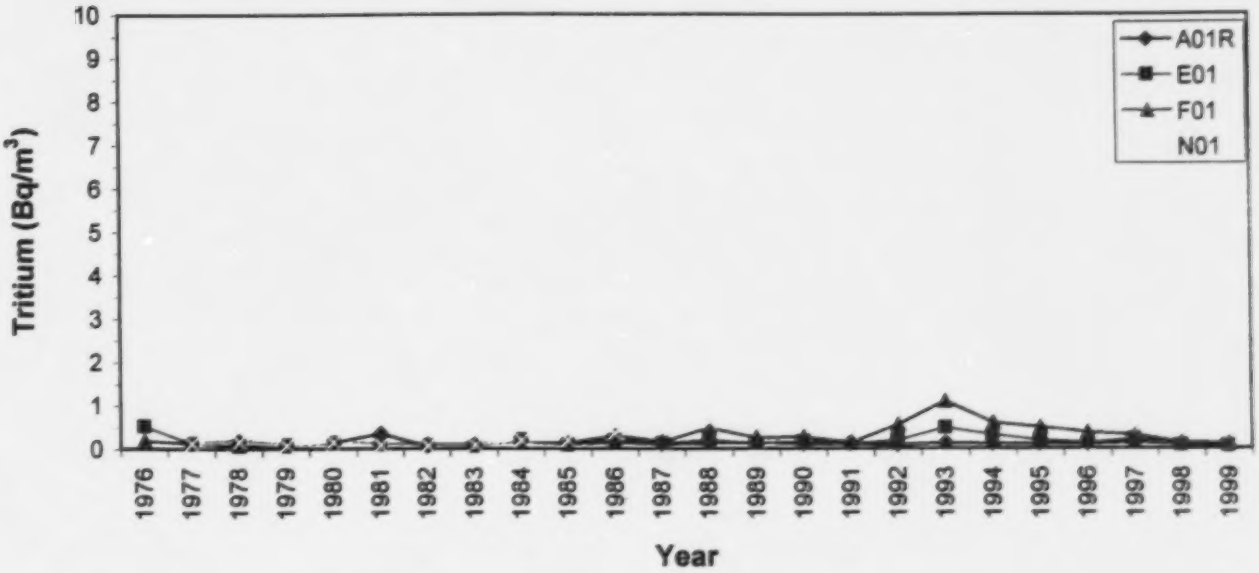

Figure 5.06
Tritiated Water in Air (Offsite)

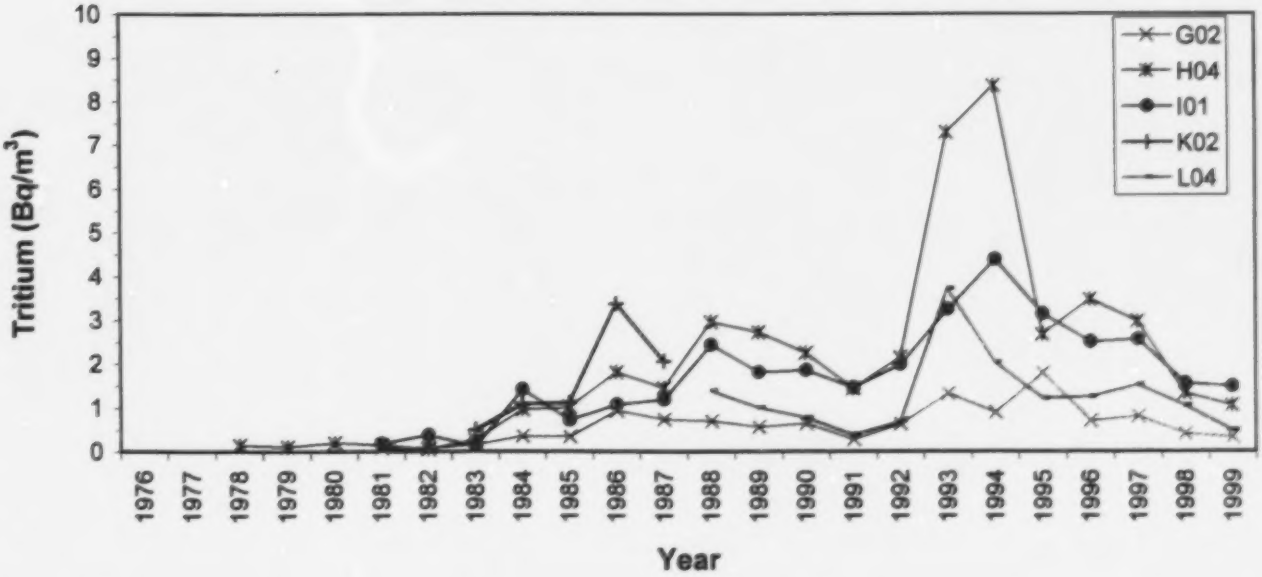

Figure 5.07
Tritiated Water in Air (Onsite)

Atmospheric Dispersion Factors

The annual average dispersion factor for stack emissions up to this time is between 1E-7 and 2E-7 s/m^3. This factor is based upon the data for H-3. A value of 2E-7, based on such empirical data, is used in the DEL calculations. Results since 1984 are presented in Table 5.01.

In the calculation of the mean dispersion factor at each location, the average recorded is now the average of the detected values and the "Less Than" values. This will give a conservative estimate of the true value (i.e. less dispersion of the radionuclides).

To derive a normalised mean dispersion factor at 1 km from the stack for all locations, each dispersion factor value is corrected to 1 km. This is accomplished by tracing back between dispersion curves on the graph of "Weighted Mean Dilution Factor versus Distance from the Point of Continuous Emission"[8]. The average of these normalised values is presented in Table 5.02.

Table 5.01
Average Atmospheric Dispersion Factor for Each Air Monitoring Location (1)

Location	E01 Maces Bay	F01 Welch Cove	G02 Light-house	H04 Duck Cove *	I01 SRWMF	K02 Pump-house	L04 Stores	N01 Dipper Harbour
km from stack	4.5	1.6	1.0	0.8	1.2	0.2	0.6	3.7
Year (+)	Dispersion Factors: s/m^3							
1984 (6.8E13)	8E-8	8E-8	2E-7	5E-7	7E-7**	5E-7		8E-8
1985 (1.1E14)	2E-8	4E-8	9E-8	3E-7	2E-7	3E-7		5E-8
1986 (2.0E14)	3E-8	5E-8	1E-7	3E-7	2E-7	5E-7		6E-8
1987 (2.2E14)	2E-8	2E-8	1E-7	2E-7	2E-7	3E-7		7E-8
1988 (2.2E14)	3E-8	7E-8	1E-7	4E-7	3E-7	#	2E-7	9E-8
1989 (2.1E14)	2E-8	4E-8	8E-8	4E-7	3E-7	#	2E-7	8E-8
1990 (2.5E14)	2E-8	3E-8	8E-8	3E-7	2E-7	#	1E-7	8E-8
1991 (1.7E14)	2E-8	3E-8	5E-8	3E-7	3E-7	#	7E-8	7E-8
1992 (3.6E14)	2E-8	5E-8	5E-8	2E-7	2E-7	#	6E-8	4E-8
1993 (6.4E14)	2E-8	5E-8	6E-8	4E-7	2E-7	#	2E-7	5E-8
1994 (5.6E14)	2E-8	3E-8	5E-8	5E-7	2E-7	#	1E-7	1E-7
1995 (3.1E14)	2E-8	5E-8	2E-7	3E-7	3E-7	#	1E-7	4E-8
1996 (2.4E14)	2E-8	5E-8	9E-8	5E-7	3E-7	#	2E-7	8E-8
1997 (2.1E14)	3E-8	5E-8	1E-7	4E-7	4E-7	#	2E-7	9E-8
1998 (1.3E14)	2E-8	3E-8	1E-7	3E-7	4E-7	#	3E-7	5E-8
1999 (9.5E13)	7E-8	5E-8	1E-7	3e-7	5e-7	#	1E-7	1E-7

\+ Becquerel of tritium as tritiated water, emitted during the year.
(1) Excluding the Reference location A01R.
* This location was identified as "Information Centre" in previous reports.
** This value includes a second source term: H-3 from containers temporarily located in this facility in 1984 and picked up by the air sampler (ignored in the calculation of the normalised mean dispersion factor).
\# No longer in use. This monitoring station was relocated to L04 - the Construction Stores Compound - in the spring of 1988.

Table 5.02
Normalised Mean Dispersion Factor
At 1 km For All Indicator Locations

Year	s/m^3
1984	2E-07
1985	1E-07
1986	1E-07
1987	1E-07
1988	2E-07
1989	2E-07
1990	1E-07
1991	1E-07
1992	1E-07
1993	1E-07
1994	1E-07
1995	2E-07
1996	2E-07
1997	2E-07
1998	2E-07
1999	2E-07
Average over 16 years	<2E-07

Figure 5.08 Strontium-90 in Air (GEM)

There have only been a few years when Sr-90 was detected in station effluents. The maximum values for Sr-90 still represent only a small fraction of the DEL and are due to activity detected just above the detection limit.

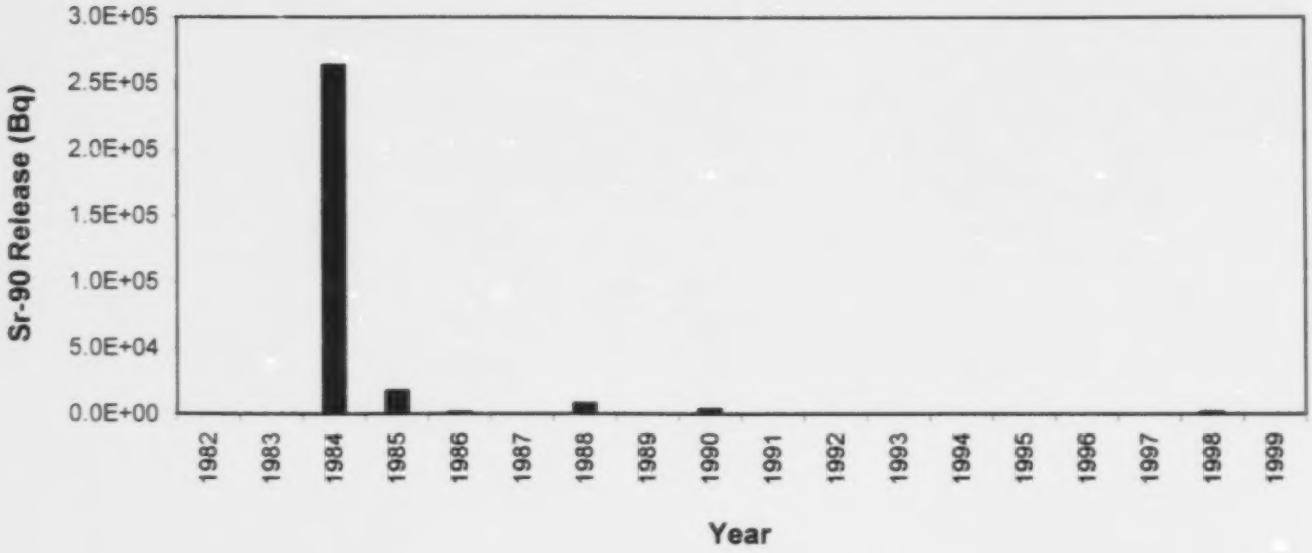

Figure 5.08
Sr-90 in Air (GEM)

Figure 5.09 TLD Measurements

A plot of summary TLD data since 1978 is presented in Figure 5.09. There is only one reference location (A01R in Bocabec) while the other groups are the average of many locations.

The variation in natural background radiation at any individual location covers a range of about 300 microsieverts from year to year. A few locations (close to the reactor building and the air emissions stack) show significant, but small, increases in gamma radiation due to chronic releases of low levels of noble gases. In 1995, the extended outage resulted in fewer noble gas emissions and thus lower dose measured by these TLDs. Small increases at the SRWMF are due to low-level waste and used fuel emplacement and not to station emissions.

Background radiation in any of the monitored residential areas has not increased from the levels measured before the Point Lepreau Generating Station was placed into operation.

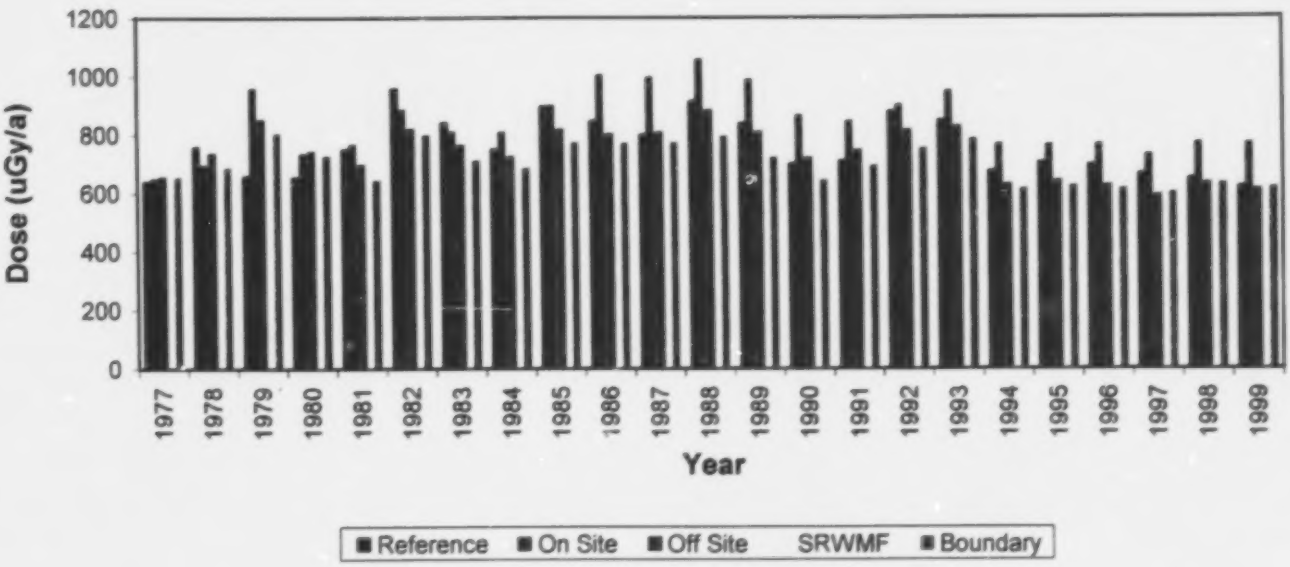

Figure 5.09
TLD Measurements

Figure 5.10 Gross Beta in Well Water

The beta activity is due to the presence of naturally occurring radionuclides (especially radon progeny). As expected, there has been no significant change in this parameter over the years.

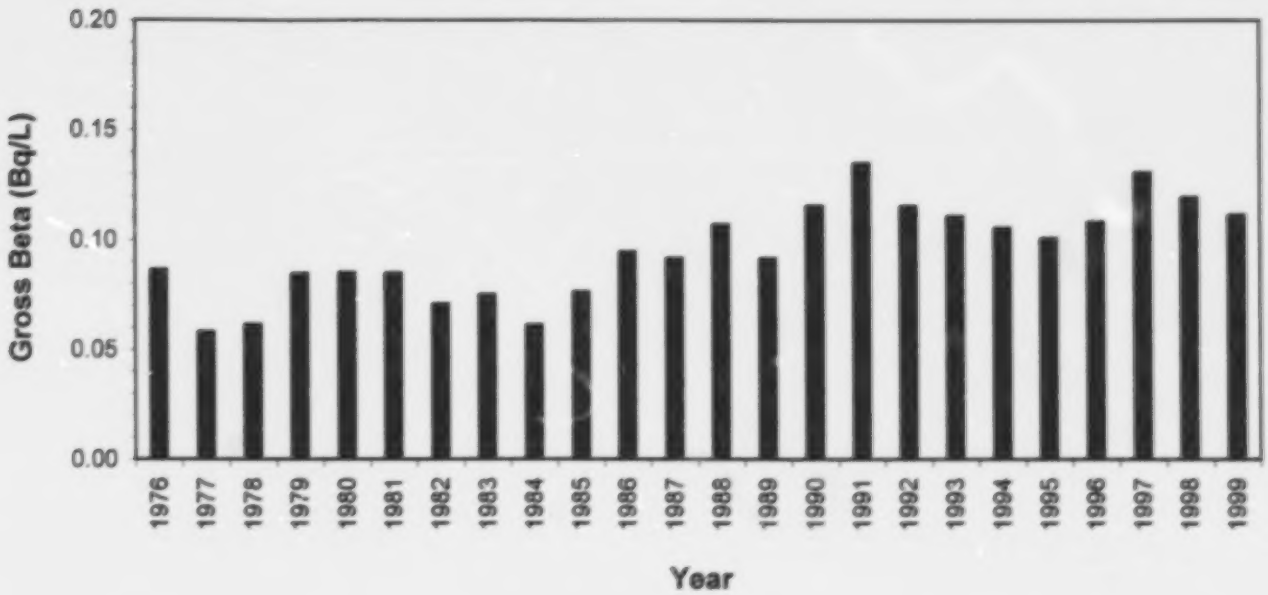

Figure 5.10
Gross Beta in Well Water

Figure 5.11 Tritium in Well Water

Precipitation and surface water contain tritium from PLGS emissions. Even though there is surface runoff into some shallow wells, there has been no significant change in this parameter over the years.

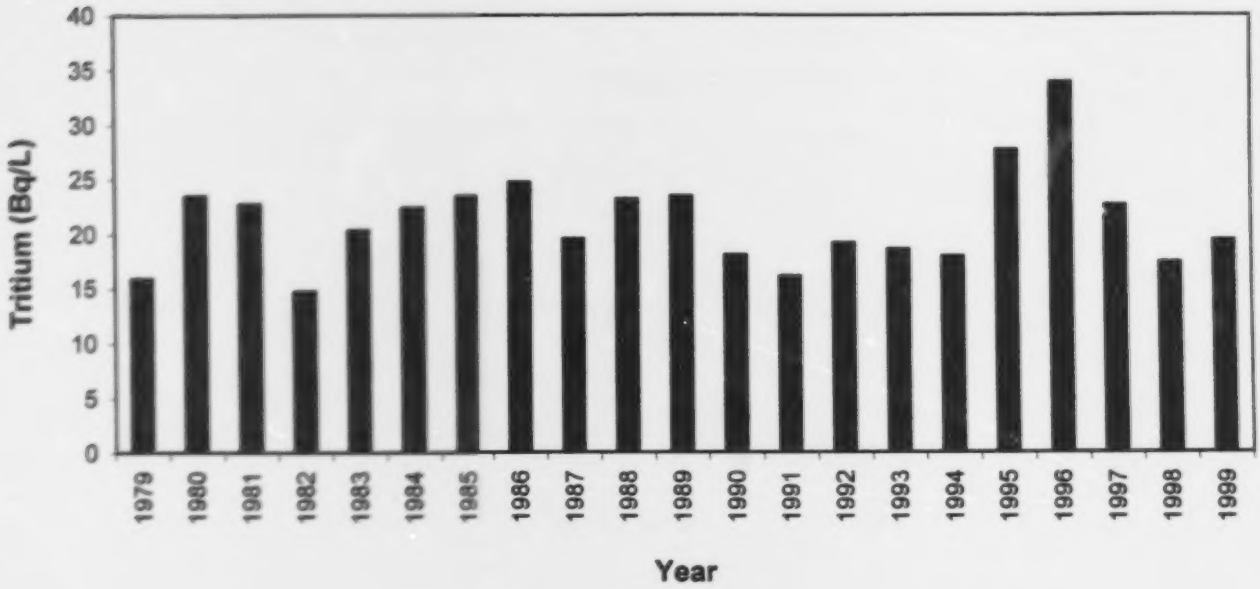

Figure 5.11
Tritium in Well Water

Figure 5.12 Cs-137 in Soil

Cesium-137 from fallout from past atmospheric bomb tests tends to accumulate in the organic layer of the soil. Any fluctuation seems to be due to this organic load in the sample. There were no soil samples from 1986 to 1992 because at the time, this fluctuation caused it to be viewed as an unimportant sample type.

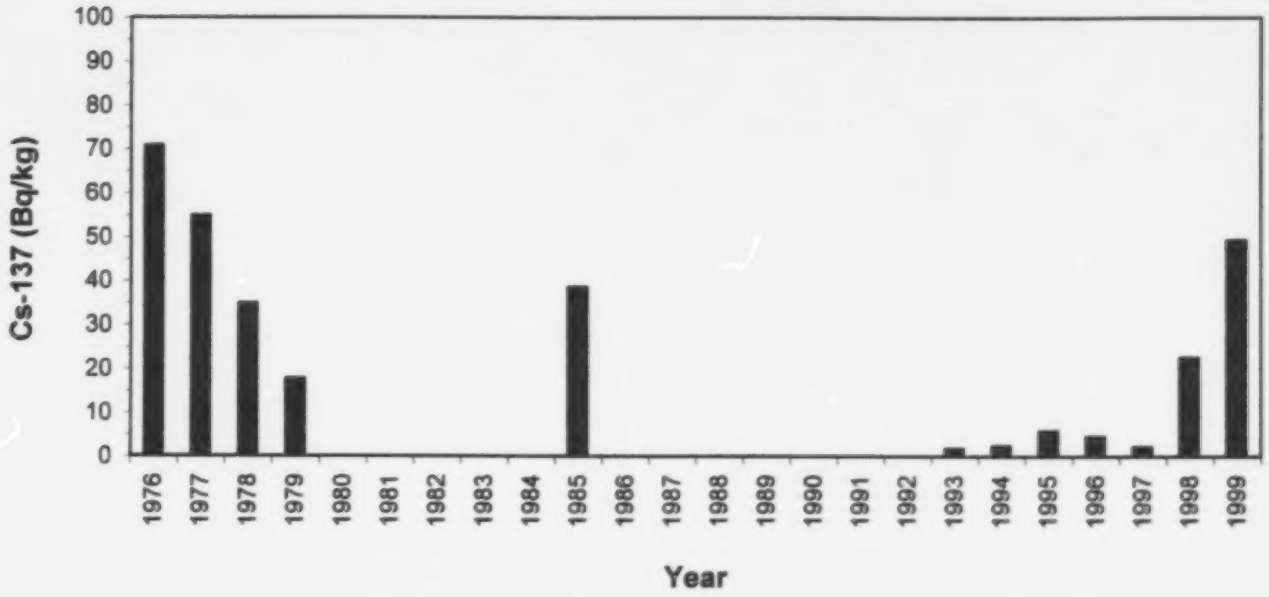

Figure 5.12
Cs-137 in Soil

Figure 5.13 Cs-137 in Sediment

The effects of the atmospheric bomb tests and the accident at Chernobyl continue to be seen here. There has been no significant change in this parameter over the years.

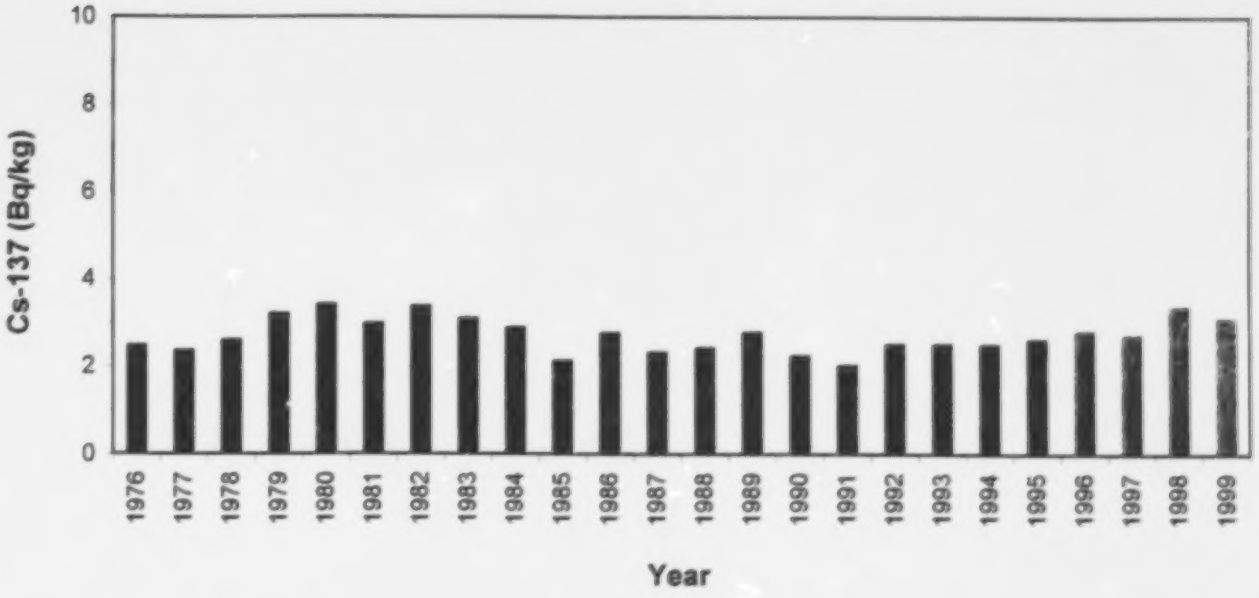

Figure 5.13
Cs-137 in Sediment

Figure 5.14 Tritium in Seawater

The increase in H-3 in 1996 and 1997 were due to samples being taken directly over the outfall. These samples are usually taken at the shore, where the effects of tidal mixing are evident.

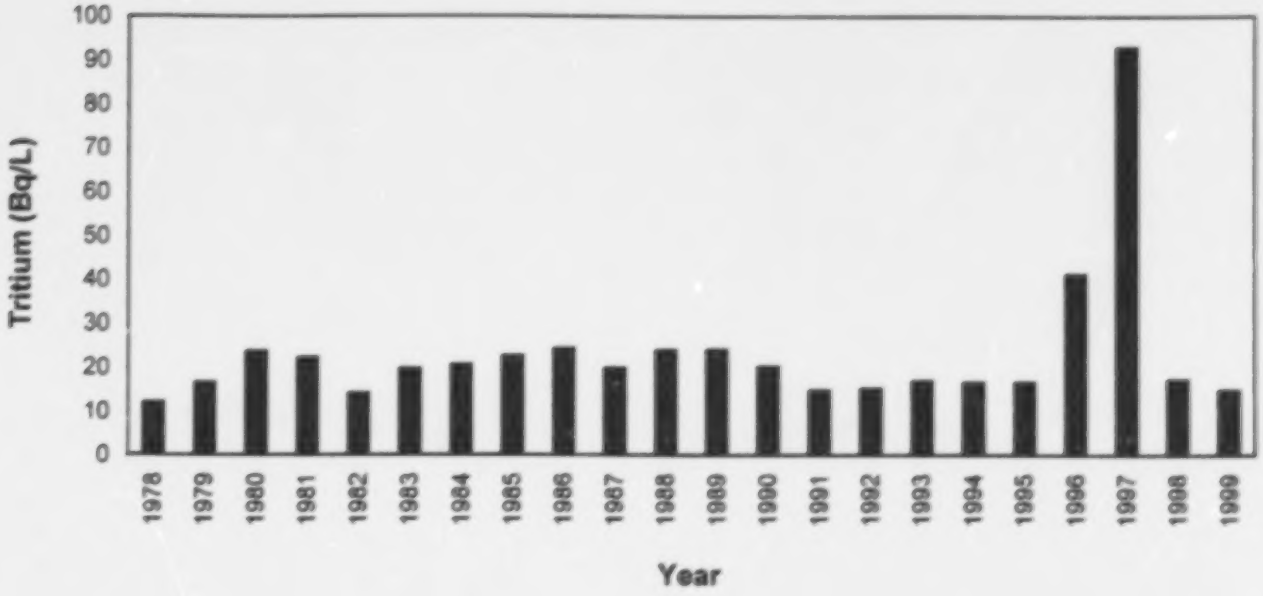

Figure 5.14
Tritium in Seawater

Figure 5.15 Strontium-90 in LEM

The maximum values for Sr-90 still represent only a small fraction of the DEL and are due to activity detected just above the detection limit.

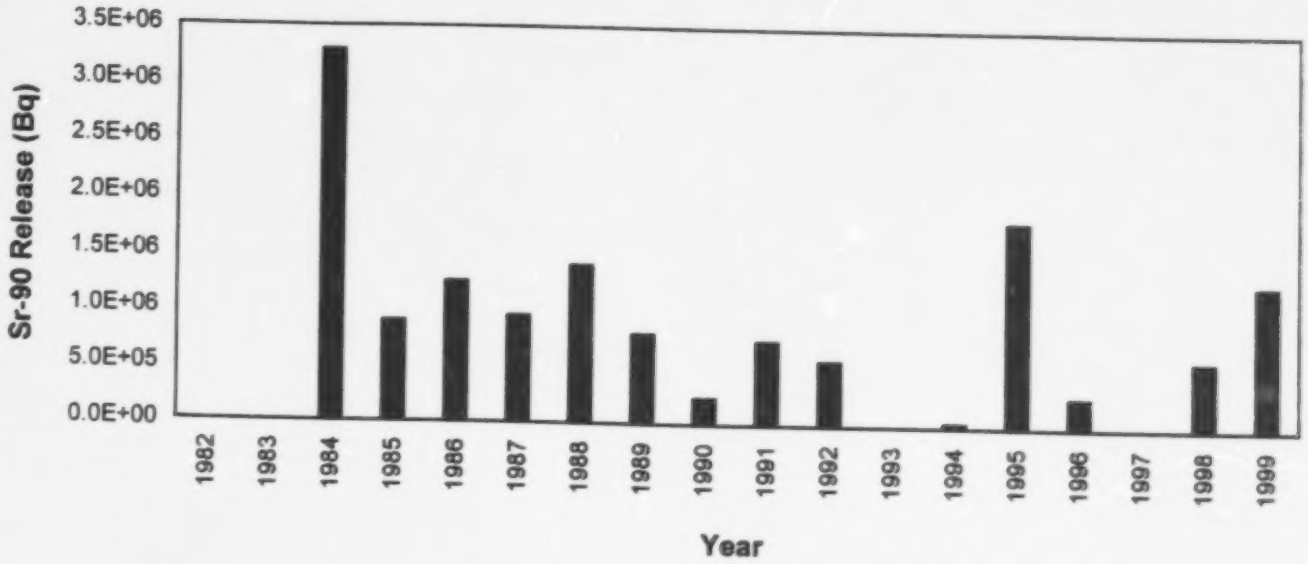

Figure 5.15
Sr-90 in LEM

Figure 5.16 to 5.20 Tritium in Bore Holes and Parshall Flumes

The values at Phase 2 are typically less than those at Phase 1, indicating possible dilution of the surface runoff to the flume or a developing problem with the Phase 1 structures. There has been a general upward trend in the Phase 1 Parshall Flume and bore hole results since the late 1980s.

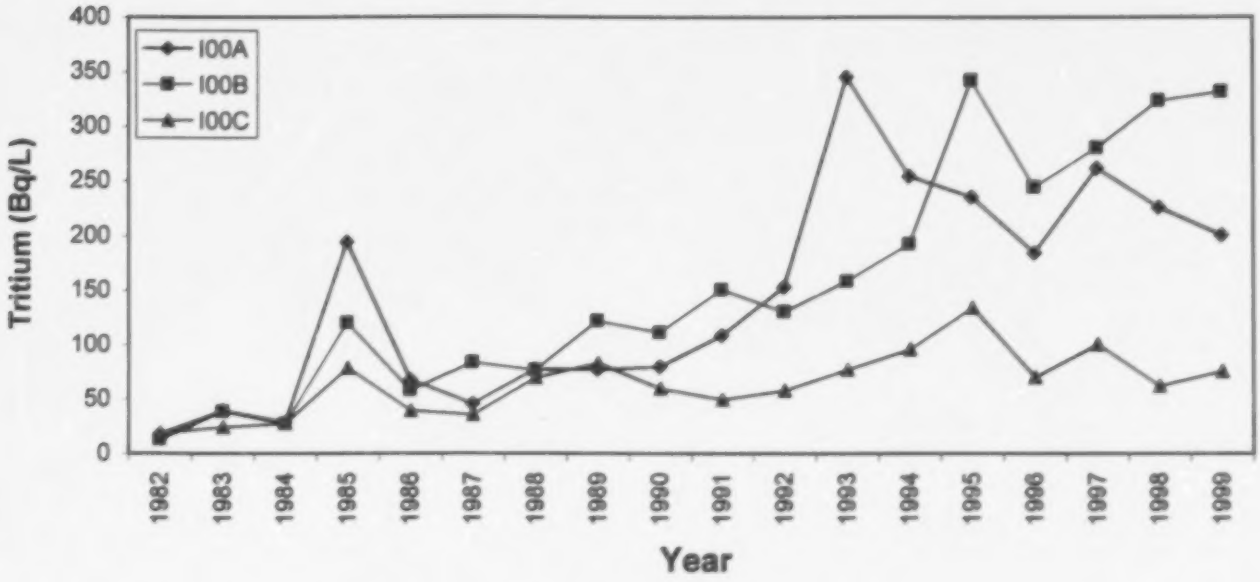

Figure 5.16
H-3 in Bore Holes

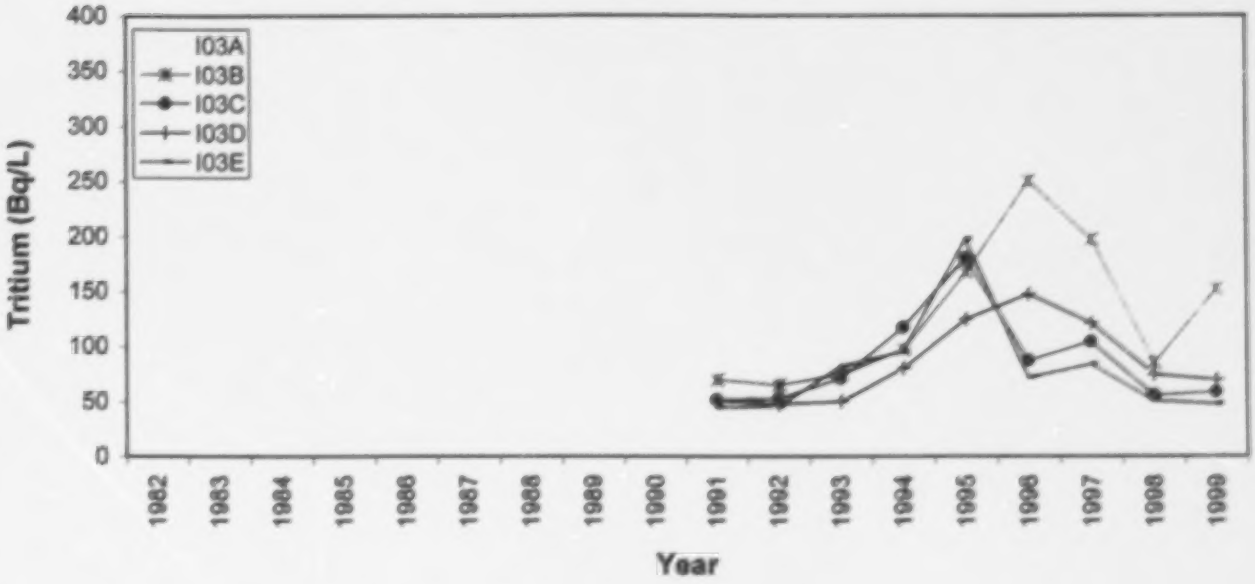

Figure 5.17
H-3 in Bore Holes

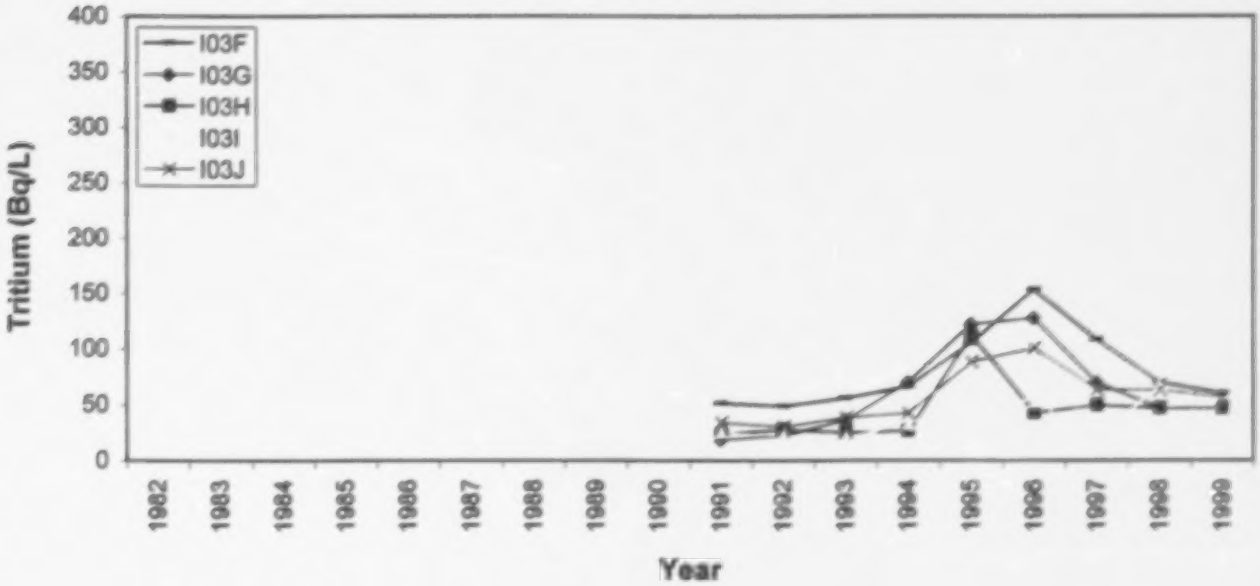

Figure 5.18
H-3 in Bore Holes

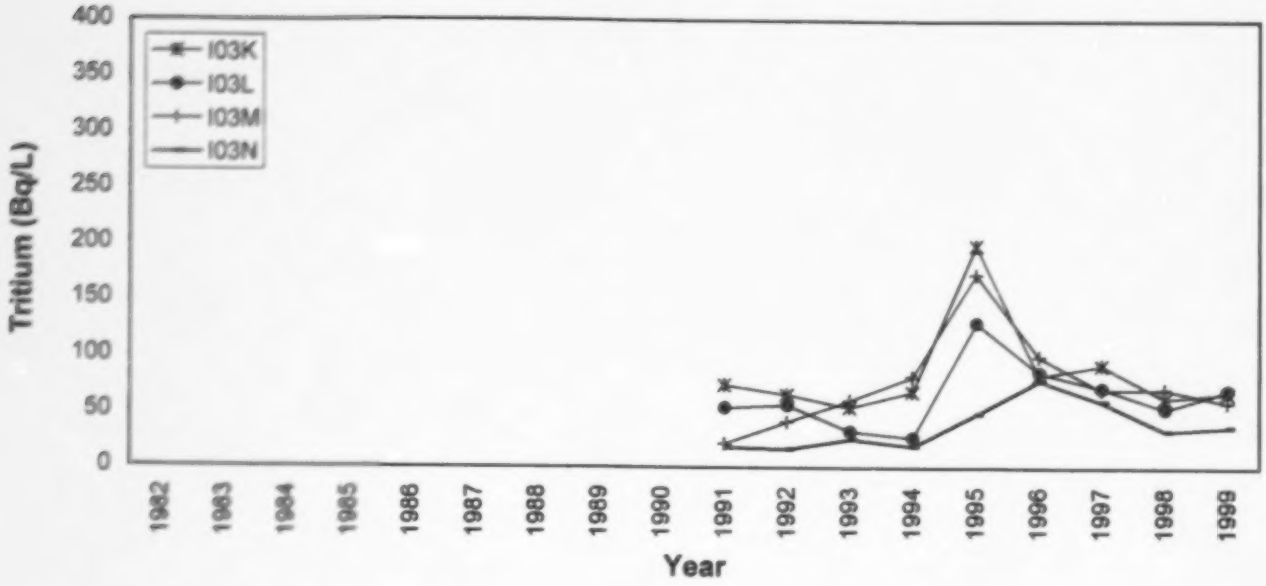

Figure 5.19
H-3 in Bore Holes

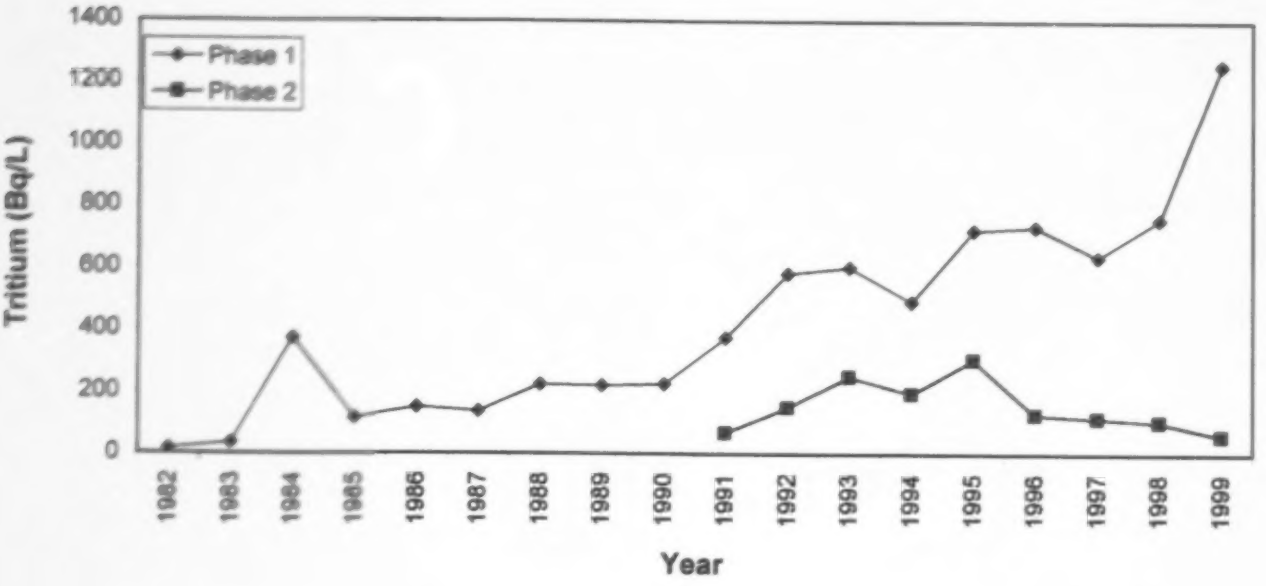

Figure 5.20
H-3 in Parshall Flumes

Figure 5.21 Drop Off TLDs

Dosimeters are in place in two directions from the boundary fence of the SRWMF - Phase 2 facility to measure drop-off of radiation from the filled dry fuel storage canisters with distance, to about 200 metres. Results are presented in Figure 5.21. Each point on the graph is the average for all the years the facility has operated. The B direction is higher than the A direction because the rocky terrain has a higher natural background.

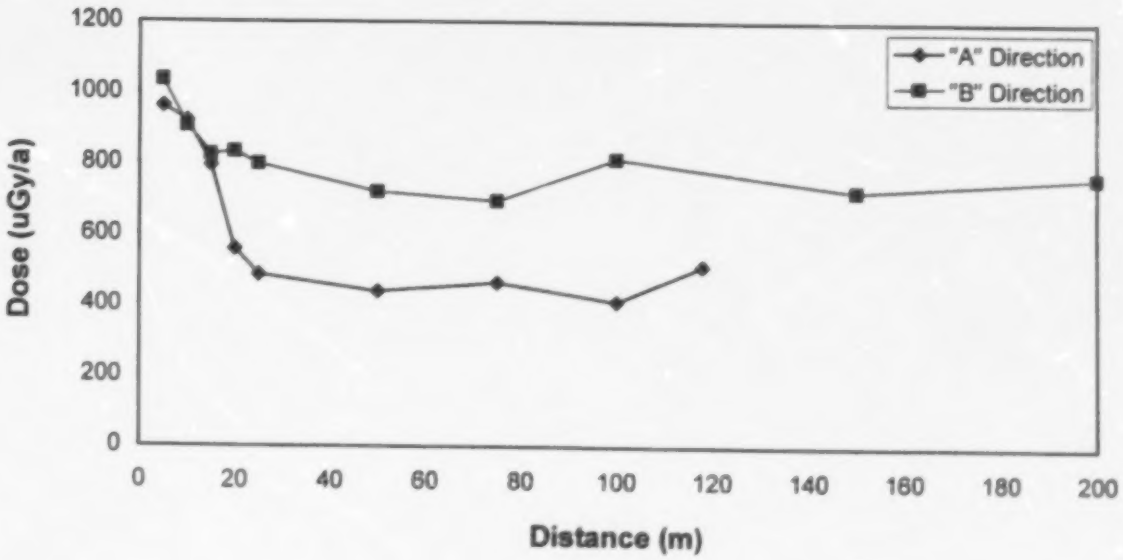

Figure 5.21
Drop off TLDs

Figure 5.22 and 5.23 Drop Off TLDs

These bar charts present the individual data points that are averaged by location (since 1991) in Figure 5.21.

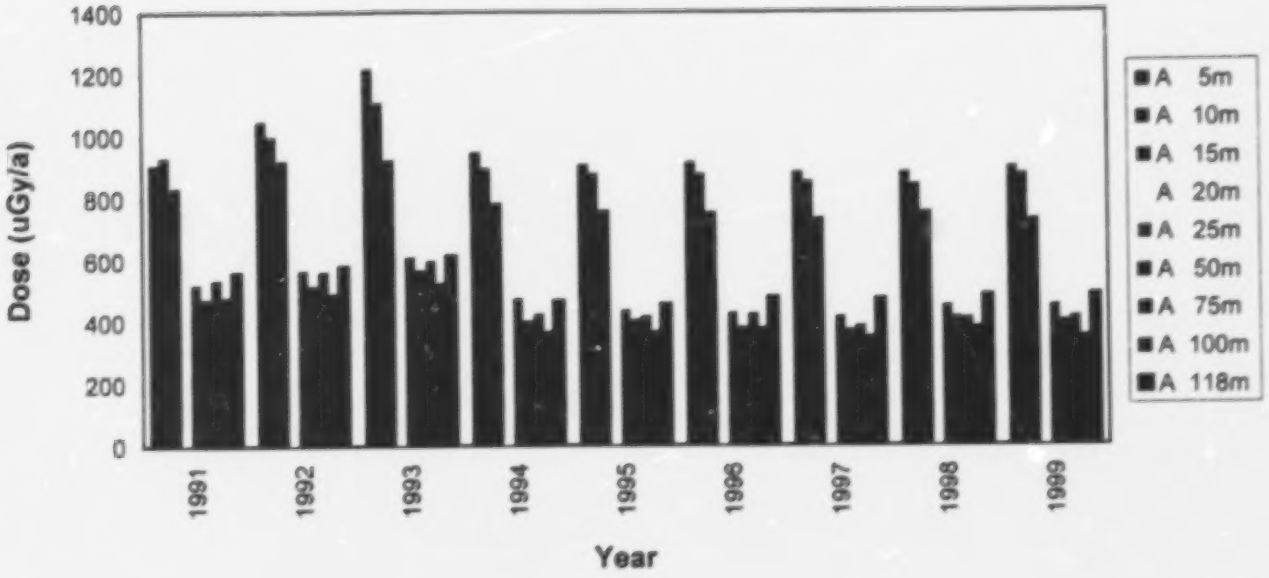

Figure 5.22
Drop off TLDs

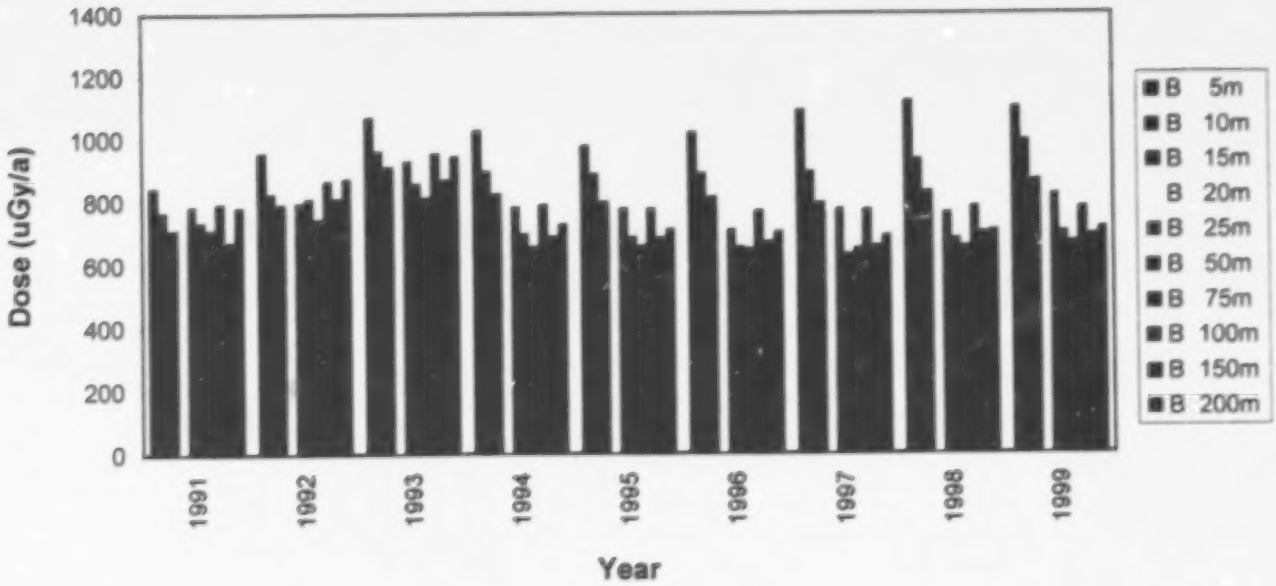

Figure 5.23
Drop off TLDs

6.0 Dose Estimation

Based upon the total percent DEL for all monitored radionuclides in each pathway for 1999, the calculated annual whole body radiation dose to members of the Critical Groups was about 0.5 μSv from liquid emissions and about 0.4 μSv from airborne emissions. This latter calculation allows for the actual location of an existing dairy herd in 1999 at about 40 km, rather than assuming the existence of a hypothetical herd at 1.5 km. This results in a dose reduction factor of about 12 for C-14 in the milk pathway because of the differences in dispersion factors between 1.5 km and 40 km (6E-08 s/m^3, and 5E-09 s/m^3, respectively).

Because of the protective assumptions used in the DEL calculations, and the relatively low level of emissions, the most exposed member of the general public received far less than the calculated dose. This radiation dose may be compared with the individual natural radiation dose in the Point Lepreau area of approximately 2000 to 3000 μSv per annum. (TLDs show only the external, penetrating component, amounting to about 500 to 1000 μSv.) This includes natural dose contributions from ground, air, food and from an assumed low concentration of radon in homes. A significant fraction of Canadian homes contain radon levels that give a radiation dose much larger than this. In addition, the average annual medical radiation dose is about 350 μSv per person.

Table 6.01
Annual Dose

Source of Dose to Critical Group	*Individual Dose (μSv/a)*	*Population Dose (person-mSv/a)*
PLGS gaseous emissions (1999)	0.4	1.4
PLGS liquid emissions (1999)	0.5	2.0
natural background (estimate)	2 000	320 000
medical procedures (estimate)	-------	80 000

The only assessable radiation dose from PLGS on the local population is that from tritiated water vapour in air. This continues to be detected offsite in air and water samples.

Population dose is the summation of all calculated doses over the entire population within a 20 km radius from PLGS for the seafood pathway, and within a 60 km radius from PLGS for the airborne pathway. This population dose for 1999 was 2.0 person-millisievert in the seafood pathway and about 1.4 person-millisieverts in the airborne pathway, for a population total of 3.4 person-millisieverts. This is insignificant when compared with the population dose of about 320 000 person-millisieverts that this same group receives from natural background radiation, and an additional 80 000 person-millisieverts received by some of this population from radiation used in medical treatments.

7.0 Quality Assurance Results

7.1 Introduction

The entire OERMP is reviewed on an annual basis to ensure all objectives are being met. Details are provided in section 7.5.

The Quality Assurance (QA) program faced a challenge in 1999 from the elimination of the United States Environmental Protection Agency (USEPA) and Atomic Energy of Canada Limited (AECL) programs. This deficiency was balanced by an increase in other QA activity.

- Analytical checks are conducted daily, and the use of indicator radionuclides such as K-40 shows that the analyses are reproducible.

- Environmental monitoring for the Point Lepreau area has been conducted in previous years by the Bedford Institute of Oceanography (Dartmouth, Nova Scotia) and the Federal Department of Health (Ottawa). The analytical results reported by these agencies were comparable with those reported by NB Power for similar samples.

- The laboratory also contracted out its services in 1999 for several clients. A calibration standard was run with each set of samples to indicate to the customer the reliability of the results. These results are presented in Figures 7.01 to 7.03. This process, combined with the general agreement between the results we reported to the customer and their own results, provides an extra degree of confidence in the Environmental Program.

- Internal Quality Control checks and calibrations, traceable to U.S. or Canadian National Standards, are performed each work day and are routine for all analytical techniques in the Health Physics Environmental Laboratory.

All QA results obtained to date show that the required degree of accuracy and precision is achieved. However, the lack of an external blind program is recognized as being inadequate. As part of the new OERMP being introduced in 2000, several outside suppliers of blind samples have been identified.

7.2 Quality Control

At the beginning of each day, the four main pieces of analytical equipment have a quality control check performed on them. Key instrument parameters are checked and the results are compared against tolerance limits, and are also compared with previous results to detect trends in performance. To perform the quality control checks, radiation sources traceable to US or Canadian standards (NIST and National Research Council) are used. Failures are investigated immediately.

The daily Quality Control (QC) evaluations in the laboratory cover the following instruments:

1. Canberra intrinsic Ge Gamma Spectrometer
2. Beckman Liquid Scintillation Counter
3. Tennelec LB-5100 Gross Alpha/Beta Detector
4. Panasonic UD-710A TLD Reader

In the QC program, the operating parameters of each of the major instruments are evaluated at the start of each working day. This ensures that they are consistent and remain free from significant drift or random variation that could influence the analyses. A compilation of the results and statistical fluctuations is maintained, and from these data the upper and lower flag limits are determined. If any equipment exceeds these limits, it is not used for any analytical work until the problem has been resolved.

Intrinsic Ge Gamma Spectrometer

A daily check of seven system parameters is performed for the germanium gamma spectrometry system. Measurements are made of the energy centroids, full width half maxima (FWHM) and efficiencies of two widely separated photon energies of Eu-152. These show the accuracy and precision of the system relative to the defined limits of acceptance. The rate of liquid nitrogen consumption is monitored to verify the physical integrity of the cryostat. The results are processed by a computer program that generates QC plots and performs statistical tests to detect out-of-range values. A 200 000 s background count is made each weekend to ensure the absence of contamination in the sample chamber. The total counts in eight separate regions of the background spectrum are evaluated by the QC program, and out-of-range values are flagged for assessment.

The efficiency calibration of the gamma spectrometry system is checked annually for each of the counting geometries. This is accomplished using a mixed nuclide standard traceable to the U.S. National Institute of Standards and Technology (NIST).

Beckman Liquid Scintillation Counter (model LS6000 TA)

A set of sealed tritium, C-14 and background standards traceable to NIST is analysed daily. Statistical parameters must lie within defined limits or the equipment will not be used. These same standards are used to calibrate the instrument for each analysis run.

Tennelec LB-5100 Gross Alpha/Beta Detector

Planchet standards of Am-241 and Sr,Y-90 are analysed daily. Alpha and Beta discrimination allows the simultaneous analysis of alpha and beta emissions on all samples analysed. Planchet and filter backgrounds are included in the QC checks. These same standards are used to calibrate the instrument for each analysis run.

Panasonic UD-710A TLD Reader

A set of 16 TLDs is exposed in the Panarad Irradiator and read out in the TLD reader. The mean of each of the four elements, dark current, reference light, reference element, and lamp flashes must all be within specified limits. The QA aspect of this system is covered in detail in *External Beta/Gamma Dosimetry Program*[9].

Other Instruments

Other instruments (balances, pipettes) are checked or calibrated at least annually. See the "Calibration, Maintenance and Repair" section of *Environmental Radiation Monitoring Program Procedures*[10]. Frequencies of calibration are based on reproducibility of measurements and on time stability tests to ensure that the measurements made are within the specified tolerances for accuracy.

The gamma survey meter is calibrated at PLGS on an annual basis.

7.3 External Intercomparison Programs

None was available in 1999.

Figure 7.01 shows the results for the repeated analyses of the different standards used to calibrate the gamma spectroscopy system. Figures 7.02 to 7.03 show the results of repeated analyses of a stock. solution of H-3 and C-14. These results provides a degree of confidence in the Environmental Program that is lacking due to the absence of an external blind program. New sources of blind samples have been identified for 2000.

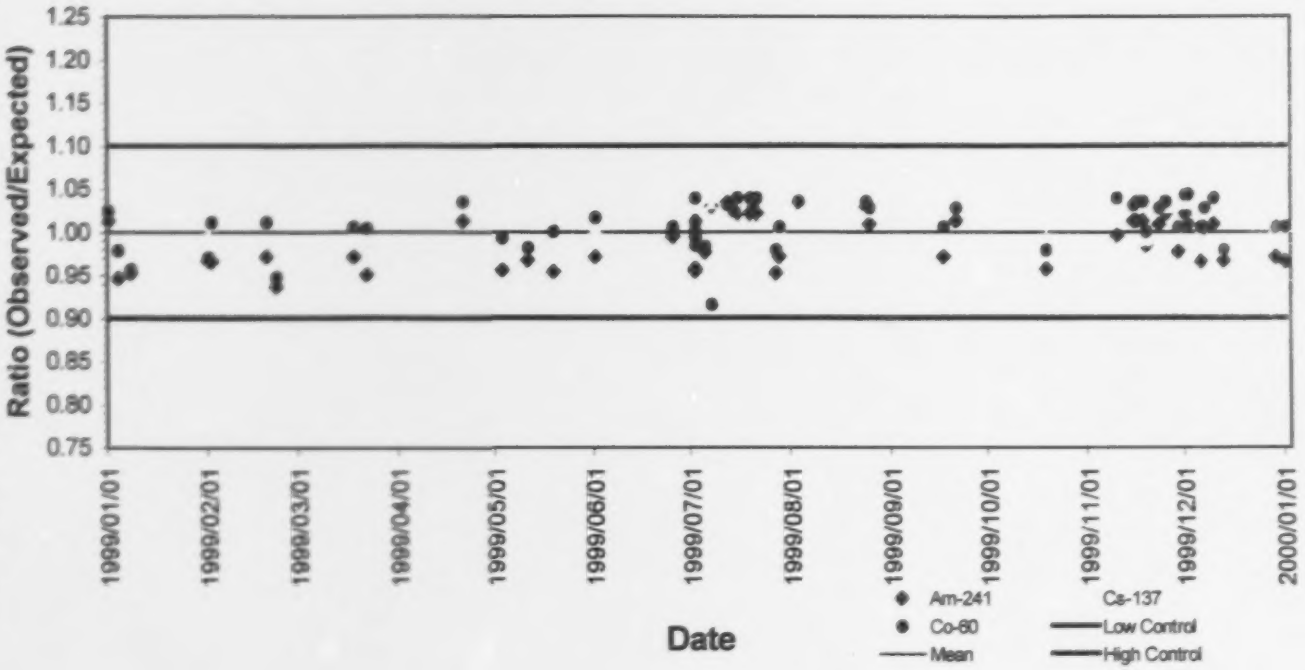

Figure 7.01
Gamma QA
Repeated Analyses of Calibration Standards

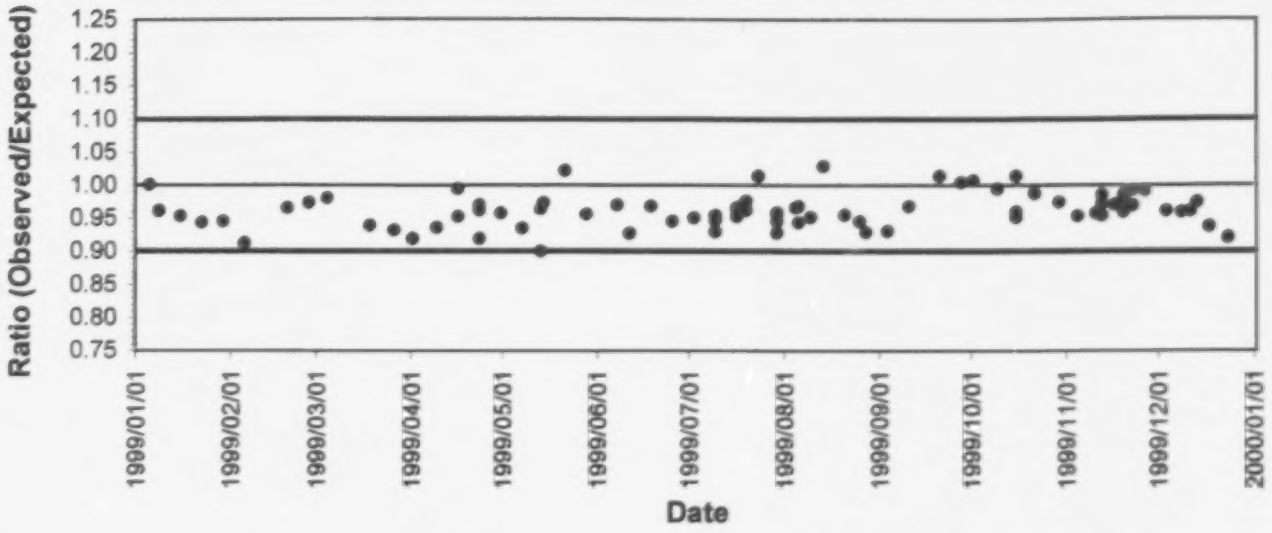

Figure 7.02
Tritium QA
Repeated Analyses of Standard Solution

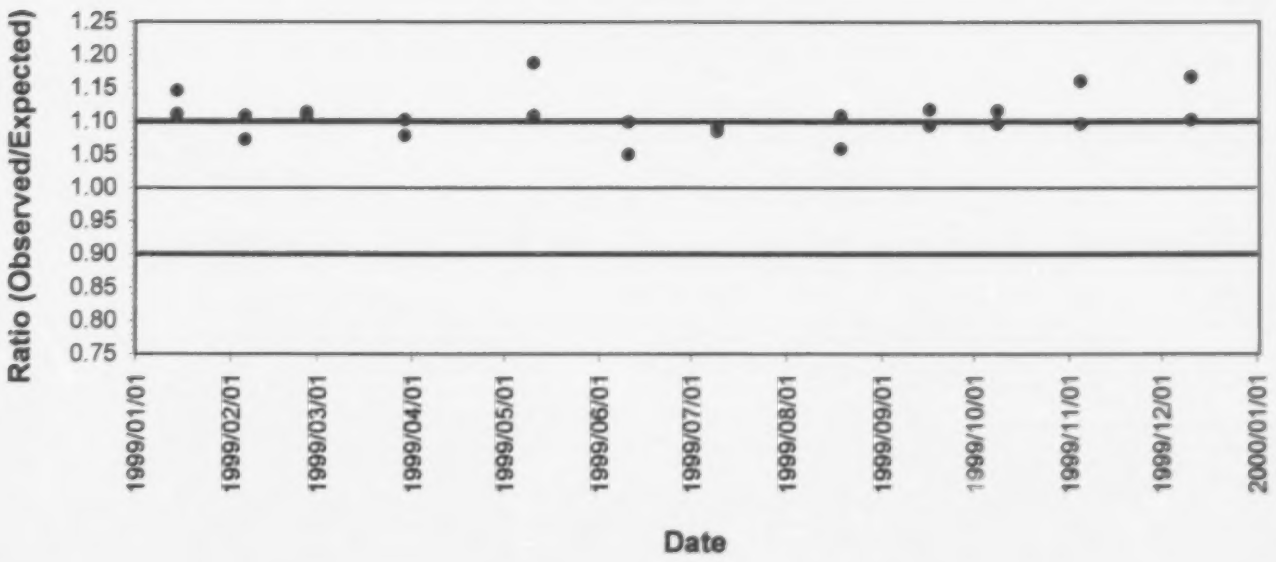

Figure 7.03
Carbon-14 QA
Repeated Analyses of Standard Solution

7.5 Annual Review

A major review of the program by all lab staff takes place each year. Generally, all aspects of the program are looked at to ensure the objectives, as stated in this document, are being met. Major areas addressed are:

1) results (consistency and trends)
2) procedures (field and lab)
3) QA results
4) status of equipment
5) training of personnel
6) safety
7) emissions
8) meteorological data
9) Emergency Measures Organization data

As part of the annual review, the following considerations are re-evaluated:

- appropriateness of samples and sample stations
- redundancy of different environmental media (i.e., testing more media than necessary)
- frequency of sampling
- number of samples necessary

Throughout the year these same areas are addressed more informally at the lab meetings. Deficiencies observed are dealt with immediately.

Other areas that are addressed throughout the year as well as during the annual review are:

- high LLDs
- unexpected radionuclides
- unexpected levels of radionuclides
- daily QC biases & trends
- QA biases and trends
- errors in results

Deficiencies in these areas are dealt with promptly.

Appendices

Appendix A
Statistics, Detection Limits, and Dose at Detection Limits

A.1 Statistics

The following statistical conventions are applied in the analysis of each sample:

1. Detection limits are defined following the method described by Lochamy[11]. The lower limit of detection (LLD) at the 99% confidence level is defined as 6.58 S_b, where S_b is the standard deviation of the appropriate radiation background measurement. This LLD corresponds to that amount of activity in a sample that will yield a net count greater than 3.29 S_b, or the so-called critical level (CL), with 99% probability. Thus, the LLD specifies the theoretical capability of the system to detect a given amount of radioactivity, whereas CL is used to determine whether an actual activity measurement should be considered detected. Any net measurement greater than 3.29 S_b is considered detected at the 99% confidence level. This also implies a 1% probability of stating that activity is present when it is not (false positive). If activity is present at the LLD level (6.58 S_b), there is a 1% probability of stating that activity is not present when it is (false negative).

   The CL of 3.29 S_b and LLD of 6.58 S_b apply in those analytical systems where the background levels are either not well defined, or where there is a relationship between the background levels and the detected signal above background, as in Ge gamma spectrometry. Where the background readings are well defined and are independent of sample readings, as in the TLD data, the CL is 2.33 S_b and the LLD is 4.66 S_b.

   In most of the tables of data (Section 3.0), it is this Critical Level that appears in column 2.

2. Unless otherwise indicated, the precision of the measurements reported here is given as $\pm$ 1.96 S_a (95% confidence level), where S_a is the standard deviation of the activity measurement.

3. The value and standard deviation are reported with two significant figures using modified scientific notation, for example 0.032 is expressed as 3.2E-02.

The lower limits of detection (LLD) of all radionuclides in the various sample media are shown in Tables A.01 to A.11. The Annual Dose is to a member of the Critical Group. The LLDs are based on typical data. Decay of radionuclides is accounted for in the LLD calculations except for H-3 and C-14 (long half-lives). The major assumptions are that the sample is taken at one kilometre from the point of emissions and that the level is maintained for the year. Milk is assumed to be from a cow pastured at 1.5 km, fish and lobster are caught at the CCW outlet and sediment, dulse, seawater and clams are collected at Dipper Harbour.

The CSA recommends, where technically feasible, that all measurements achieve LLDs less than that which would result in a dose of 5 μSv to the Critical Group. Most radionuclides pass this

criterion. The major exceptions are noble gases. Detection of this group is through TLD measurements (20 μSv dose to the Critical Group at the LLD). However, the noble gas spectrometer on the gaseous effluent monitor allows for a much smaller LLD calculation. Other exceptions are Ba-140 in soil and sediment (10 to 12 μSv); Ru-106 in water and clams (7 to 17 μSv); Ce-144 in water (11 μSv); and I-131 in food (8 μSv). Effluent analyses show these are not major components of release. Part of the QA process identifies those LLDs or activities that do not meet this target.

Airborne Particulates - Typical LLDs are given for a 2400 m^3 sample, counted for 5000 s. The LLDs are decay corrected to the midpoint between the start and end of sampling, except for the gross alpha/beta results which represent the long-lived activity present a few days after sample collection. Gross alpha/beta is for trending only.

Airborne Radioiodines - A typical LLD for I-131 is 8E-05 Bq/m^3 (for a 2400 m^3 sample, counted for 50 000 s), which is decay corrected to the midpoint between the start and end of sampling.

Airborne Tritium - The LLD is approximately 1E-01 Bq/m^3 of air for a typical sample of 10 to 70 m^3 (counted for 100 min). Due to the long half-life and relatively short period of time between sampling and analysis, decay correction is not applied.

Airborne Carbon-14 - A typical LLD is about 4E-02 Bq/m^3 of air for a 30 m^3 sample (counted for 100 min). Due to the long half-life and relatively short period of time between sampling and analysis, decay correction is not applied. Since a new method of carbon-14 analysis will be instituted with the revised program, this LLD is an estimate.

TLD - The LLD is about 20 μSv. For typical quarterly measurements in the region of 150-200 μSv, measurements can be made to ± 10% at the 95% confidence level.

Table A.01
Annual Dose at the LLD for Air

Nuclide	*LLD (Bq/m^3)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/m^3)*
H-3	9.6E-02	4.8E-02	9.9E+00
C-14	4.0E-02	1.9E+00	1.0E-01
Cr-51	5.8E-04	3.2E-03	9.2E-01
Mn-54	7.8E-05	9.2E-02	4.3E-03
Fe-59	1.7E-04	6.1E-02	1.4E-02
Co-58	8.0E-05	3.5E-02	1.2E-02
Co-60	8.2E-05	1.7E+00	2.4E-04
Zn-65	1.9E-04	3.3E-01	2.9E-03
Kr-85	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-85m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-87	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Kr-88	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Zr-95	1.3E-04	1.1E-01	6.2E-03
Nb-95	9.4E-05	9.9E-02	4.7E-03
Ru-103	7.4E-05	8.1E-03	4.5E-02
Ru-106	6.0E-04	1.0E+00	2.9E-03
Ag-110m	6.2E-05	2.2E-01	1.4E-03
I-131	8.4E-05	1.6E-01	2.5E-03
Xe-131m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-133	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-133m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-135	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-135m	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Xe-138	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Cs-134	6.4E-05	4.3E-01	7.4E-04
Cs-137	6.6E-05	1.6E+00	2.0E-04
Ba-140	4.8E-04	8.9E-02	2.7E-02
La-140	2.0E-04	2.5E-03	4.1E-01
Ce-141	7.6E-05	4.8E-03	7.9E-02
Ce-144	2.2E-04	2.7E-01	4.0E-03
Noble Gases	2.0E+01 µSv	2.0E+01	5.0E+00 µSv
Gross Alpha	6.6E-06		
Gross Beta	1.7E-05		

Milk - Typical LLDs for the nuclides of interest in milk (a 3.6 L sample counted for 50 000 s for gamma; 6 mL sample counted for 100 min for tritium) are listed in Table A.02 for the time of sample collection.

Table A.02
Annual Dose at the LLD for Milk

Nuclide	*LLD (Bq/L)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/L)*
H-3	2.4E+01	3.1E-01	3.9E+02
Cr-51	6.4E-01	1.0E-02	3.1E+02
Mn-54	9.2E-02	1.9E-02	2.5E+01
Fe-59	2.2E-01	2.2E-01	5.1E+00
Co-58	9.0E-02	7.5E-02	6.0E+00
Co-60	1.1E-01	9.0E-01	6.1E-01
Zn-65	2.4E-01	5.3E-01	2.3E+00
Zr-95	1.6E-01	4.3E-02	1.8E+01
Nb-95	9.2E-02	1.2E-01	3.8E+00
Ru-103	8.4E-02	1.9E-02	2.2E+01
Ru-106	7.8E-01	2.7E+00	1.4E+00
Ag-110m	8.2E-02	5.5E-02	7.4E+00
I-131	9.4E-02	1.8E+00	2.6E-01
Cs-134	7.8E-02	3.1E-01	1.3E+00
Cs-137	9.8E-02	3.1E-01	1.6E+00
Ba-140	3.4E-01	2.1E-01	8.1E+00
La-140	1.1E-01	8.9E-02	6.1E+00
Ce-141	1.2E-01	3.0E-02	2.1E+01
Ce-144	5.0E-01	9.5E-01	2.6E+00

Water - The LLDs in Table A.03 apply to the time of sample collection for a 3.6 L sample counted for 5000 s for gamma and a 6 mL sampled counted for 100 min for tritium. Alpha/beta results (a 200 mL sample counted for 100 min) represent the long-lived activity present several days after sample collection.

The LLDs are based on typical data for rainwater (the only water sample that has significant decay before analysis). Since decay of radionuclides is accounted for in the LLD calculations, Well Water and other water sample types will have lower LLDs than these. The major assumptions are that the sample is taken at one kilometre from the point of emissions, that the level is maintained for the year and the sample type is the major source of drinking water. Obviously this is not the case but it gives a simple "worst case" that is easy to monitor and calculate.

Table A.03
Annual Dose at the LLD for Water

Nuclide	*LLD (Bq/L)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/L)*
H-3	2.4E+01	3.4E-01	3.6E+02
Cr-51	5.4E+01	7.4E-02	3.7E+03
Mn-54	5.0E-01	1.7E-01	1.4E+01
Fe-59	1.3E+00	9.1E-01	7.1E+00
Co-58	5.6E-01	3.7E-01	7.5E+00
Co-60	4.6E-01	4.5E+00	5.1E-01
Zn-65	1.1E+00	2.3E+00	2.4E+00
Zr-95	9.8E-01	4.0E-01	1.2E+01
Nb-95	6.8E-01	4.0E-01	8.5E+00
Ru-103	6.4E-01	1.8E-01	1.8E+01
Ru-106	4.6E+00	1.7E+01	1.4E+00
Ag-110m	4.6E-01	6.2E-01	3.7E+00
I-131	2.4E+00	3.9E+00	3.1E+00
Cs-134	4.4E-01	4.8E+00	4.6E-01
Cs-137	5.2E-01	3.9E+00	6.6E-01
Ba-140	5.4E+00	2.7E+00	1.0E+01
La-140	2.2E+00	9.1E-01	1.2E+01
Ce-141	8.4E-01	3.4E-01	1.2E+01
Ce-144	2.4E+00	1.1E+01	1.1E+00
Gross Alpha	1.2E-01		
Gross Beta	8.4E-02		

Food - The LLDs in Table A.04 apply to the time of sample collection. Samples are counted for 5000 s (size varies). The LLDs are based on typical data for garden vegetables. Garden vegetables have significant radioactive decay before analysis (the local residents harvest them and store them in their freezers for varying lengths of time). Since decay of radionuclides is accounted for in the LLD calculations, berries and other food sample types (which experience less radioactive decay) will have lower LLDs than these.

Table A.04
Annual Dose at the LLD for Food

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	3.0E+01	5.9E-02	2.5E+03
Mn-54	3.4E+00	1.3E-01	1.3E+02
Fe-59	7.8E+00	8.4E-01	4.6E+01
Co-58	3.6E+00	3.0E-01	6.0E+01
Co-60	3.8E+00	3.9E+00	4.9E+00
Zn-65	9.0E+00	2.2E+00	2.1E+01
Zr-95	6.2E+00	3.3E-01	9.4E+01
Nb-95	4.0E+00	3.6E-01	5.6E+01
Ru-103	3.8E+00	1.7E-01	1.1E+02
Ru-106	3.0E+01	1.3E+01	1.1E+01
Ag-110m	3.0E+00	4.7E-01	3.2E+01
I-131	1.0E+01	6.9E+00	7.6E+00
Cs-134	3.0E+00	3.6E+00	4.2E+00
Cs-137	3.4E+00	2.9E+00	6.0E+00
Ba-140	2.4E+01	3.5E+00	3.5E+01
La-140	9.4E+00	1.2E+00	4.0E+01
Ce-141	4.2E+00	1.9E-01	1.1E+02
Ce-144	1.4E+01	4.9E+00	1.4E+01

Soil - The LLDs in Table A.05 apply to the time of sample collection. Samples of approximately 200 g are counted for 5000 s.

Table A.05
Annual Dose at the LLD for Soil

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	4.0E+01	2.5E-01	7.9E+02
Mn-54	5.8E+00	1.2E+00	2.5E+01
Fe-59	1.2E+01	3.1E+00	1.9E+01
Co-58	5.0E+00	1.1E+00	2.2E+01
Co-60	5.8E+00	3.2E+00	9.1E+00
Zn-65	1.3E+01	1.7E+00	3.9E+01
Zr-95	1.0E+01	5.1E+00	9.9E+00
Nb-95	6.0E+00	9.9E-01	3.0E+01
Ru-103	4.8E+00	5.1E-01	4.7E+01
Ru-106	4.6E+01	1.9E+00	1.2E+02
Ag-110m	5.2E+00	2.7E+00	9.7E+00
I-131	6.8E+00	5.2E-01	6.6E+01
Cs-134	5.2E+00	1.5E+00	1.7E+01
Cs-137	5.6E+00	7.1E-01	3.9E+01
Ba-140	2.2E+01	1.1E+01	9.6E+00
La-140	7.2E+00	*	*
Ce-141	6.8E+00	1.2E-01	2.8E+02
Ce-144	2.4E+01	2.9E-01	4.2E+02
TLD	2.0E+01 μSv	2.0E+01	5.0E+00 μSv
*Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

Seawater - The LLDs in Table A.06 apply to the time of sample collection (for a 3.6 L sample counted for 5000 s for gamma; a 6 mL sampled counted for 100 min for tritium). The dose is small due to the simple facts that the Bay of Fundy is frigid at the best of times (occupancy factor is low) and no one drinks salt water.

Table A.06
Annual Dose at the LLD for Seawater

Nuclide	*LLD (Bq/L)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/L)*
H-3	2.4E+01	9.2E-11	1.3E+12
Cr-51	2.2E+00	2.6E-10	4.3E+10
Mn-54	2.8E-01	7.9E-10	1.8E+09
Fe-59	6.2E-01	2.6E-09	1.2E+09
Co-58	2.8E-01	9.1E-10	1.5E+09
Co-60	3.2E-01	2.4E-09	6.8E+08
Zn-65	6.8E-01	1.3E-09	2.6E+09
Zr-95	5.2E-01	1.2E-09	2.2E+09
Nb-95	3.0E-01	9.3E-10	1.6E+09
Ru-103	2.8E-01	4.4E-10	3.2E+09
Ru-106	2.6E+00	1.6E-09	8.3E+09
Ag-110m	2.6E-01	2.3E-09	5.7E+08
I-131	3.6E-01	2.3E-09	8.0E+08
Cs-134	2.6E-01	1.3E-09	1.0E+09
Cs-137	3.0E-01	5.2E-10	2.9E+09
Ba-140	1.2E+00	2.6E-08	2.4E+08
La-140	4.6E-01	*	*
Ce-141	4.0E-01	1.1E-10	1.8E+10
Ce-144	1.6E+00	2.7E-10	3.0E+10
* Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

Clams - Typical LLDs are given in Table A.07 for the edible portions of clams, decay corrected to the time of sample collection. Samples are counted for 5000 s (size varies). The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.07
Annual Dose at the LLD for Clams

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	5.0E+01	2.0E-02	1.3E+04
Mn-54	7.0E+00	6.5E-02	5.4E+02
Fe-59	1.4E+01	3.1E-01	2.3E+02
Co-58	7.2E+00	1.3E-01	2.7E+02
Co-60	6.4E+00	1.8E+00	1.8E+01
Zn-65	1.4E+01	8.8E-01	7.8E+01
Zr-95	1.2E+01	1.5E-01	3.7E+02
Nb-95	6.6E+00	1.4E-01	2.3E+02
Ru-103	6.0E+00	5.5E-02	5.5E+02
Ru-106	5.8E+01	6.5E+00	4.5E+01
Ag-110m	5.8E+00	2.2E-01	1.3E+02
I-131	7.2E+00	9.5E-01	3.8E+01
Cs-134	6.6E+00	1.6E+00	2.1E+01
Cs-137	6.8E+00	1.5E+00	2.2E+01
Ba-140	2.4E+01	7.7E-01	1.6E+02
La-140	9.4E+00	2.2E-01	2.1E+02
Ce-141	7.4E+00	8.0E-02	4.6E+02
Ce-144	3.2E+01	2.6E+00	6.3E+01

Fish - Typical LLDs are given in Table A.08 for the edible portions of fish, decay corrected to the time of sample collection. Samples are counted for 5000 s (size varies).

Table A.08
Annual Dose at the LLD for Fish

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	1.3E+01	1.6E-02	4.0E+03
Mn-54	1.5E+00	5.1E-02	1.5E+02
Fe-59	3.8E+00	2.8E-01	6.8E+01
Co-58	1.5E+00	9.2E-02	8.0E+01
Co-60	1.4E+00	1.3E+00	5.4E+00
Zn-65	3.0E+00	7.0E-01	2.2E+01
Zr-95	2.2E+00	1.1E-01	1.0E+02
Nb-95	1.4E+00	1.1E-01	6.6E+01
Ru-103	1.5E+00	4.9E-02	1.5E+02
Ru-106	1.1E+01	4.4E+00	1.2E+01
Ag-110m	1.2E+00	1.7E-01	3.5E+01
I-131	7.8E+00	1.3E+00	3.1E+01
Cs-134	1.0E+00	1.2E+00	4.5E+00
Cs-137	1.4E+00	1.0E+00	7.1E+00
Ba-140	1.0E+01	7.8E-01	6.4E+01
La-140	4.6E+00	2.4E-01	9.6E+01
Ce-141	1.8E+00	6.0E-02	1.5E+02
Ce-144	5.8E+00	1.6E+00	1.8E+01

Lobster - Typical LLDs are given in Table A.09 for the edible portions of lobster decay corrected to the time of sample collection. Samples are counted for 5000 s (size varies).

Table A.09
Annual Dose at the LLD for Lobster

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	3.0E+01	1.3E-02	1.2E+04
Mn-54	2.8E+00	2.1E-02	6.7E+02
Fe-59	9.0E+00	1.5E-01	2.9E+02
Co-58	3.2E+00	6.7E-02	2.4E+02
Co-60	3.8E+00	5.4E-01	3.5E+01
Zn-65	7.8E+00	3.4E-01	1.2E+02
Zr-95	5.4E+00	6.8E-02	4.0E+02
Nb-95	4.4E+00	9.0E-02	2.4E+02
Ru-103	4.0E+00	3.1E-02	6.4E+02
Ru-106	3.0E+01	2.4E+00	6.3E+01
Ag-110m	3.4E+00	8.8E-02	1.9E+02
I-131	1.7E+01	3.3E+00	2.6E+01
Cs-134	2.8E+00	6.4E-01	2.2E+01
Cs-137	3.4E+00	4.5E-01	3.8E+01
Ba-140	3.4E+01	1.2E+00	1.4E+02
La-140	1.2E+01	4.2E-01	1.4E+02
Ce-141	4.4E+00	4.3E-02	5.1E+02
Ce-144	1.3E+01	8.7E-01	7.4E+01

Dulse - Typical LLDs are given in Table A.10 for dulse, decay corrected to the time of sample collection. Samples are counted for 5000 s (size varies). The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.10
Annual Dose at the LLD for Dulse

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	2.0E+01	2.4E-03	4.2E+04
Mn-54	3.4E+00	7.4E-03	2.3E+03
Fe-59	8.0E+00	4.4E-02	9.0E+02
Co-58	3.4E+00	1.5E-02	1.1E+03
Co-60	3.4E+00	2.1E-01	7.9E+01
Zn-65	8.2E+00	1.1E-01	3.9E+02
Zr-95	6.6E+00	1.6E-02	2.1E+03
Nb-95	3.6E+00	1.9E-02	9.5E+02
Ru-103	2.8E+00	7.1E-03	2.0E+03
Ru-106	2.6E+01	6.7E-01	2.0E+02
Ag-110m	3.0E+00	2.3E-02	6.4E+02
I-131	5.4E+00	3.0E-01	9.1E+01
Cs-134	2.8E+00	1.9E-01	7.3E+01
Cs-137	3.2E+00	1.3E-01	1.2E+02
Ba-140	1.6E+01	1.6E-01	4.9E+02
La-140	5.4E+00	2.8E-02	9.7E+02
Ce-141	3.4E+00	8.8E-03	1.9E+03
Ce-144	1.4E+01	2.4E-01	2.9E+02

Sediment - The LLDs in Table A.11 apply to the time of sample collection. Samples weighing approximately 200 g are counted for 5000 s. The major assumptions are that the sample is taken at Dipper Harbour and that the level is maintained for the year.

Table A.11
Annual Dose at the LLD for Sediment

Nuclide	*LLD (Bq/kg)*	*Dose at LLD (μSv)*	*Activity That Gives 5 μSv (Bq/kg)*
Cr-51	1.7E+01	2.1E-01	4.2E+02
Mn-54	2.8E+00	7.9E-01	1.8E+01
Fe-59	6.2E+00	2.3E+00	1.3E+01
Co-58	2.6E+00	8.4E-01	1.5E+01
Co-60	2.8E+00	2.3E+00	6.1E+00
Zn-65	6.8E+00	1.3E+00	2.7E+01
Zr-95	4.8E+00	3.9E+00	6.1E+00
Nb-95	3.0E+00	7.2E-01	2.1E+01
Ru-103	2.4E+00	3.9E-01	3.1E+01
Ru-106	2.0E+01	1.5E+00	6.6E+01
Ag-110m	2.2E+00	2.1E+00	5.3E+00
I-131	3.4E+00	4.7E-01	3.6E+01
Cs-134	2.0E+00	1.2E+00	8.7E+00
Cs-137	2.8E+00	6.2E-01	2.3E+01
Ba-140	1.2E+01	1.0E+01	5.8E+00
La-140	3.8E+00	*	*
Ce-141	3.0E+00	8.9E-02	1.7E+02
Ce-144	1.1E+01	2.1E-01	2.7E+02
gamma meter	0.01 μSv/h	3.0E+00	1.7E-02
* Dose for Ba-140 assumes equilibrium with La-140 (contribution from both)			

Appendix B
Sample Collection and Analytical Techniques

B.1 Analytical Techniques

All environmental samples are analysed at the Health Physics Environmental Laboratory in Fredericton. The following pages provide a general summary of the analytical techniques used in the laboratory. Sample collection, preparation and analysis are briefly described, but can be found in detail in the laboratory procedures.

The major analytical techniques and the instruments used in routine environmental analyses are summarised in the Table B.01.

Table B.01
Summary of Analytical Techniques

Analytical Technique	Instrumentation
Gamma Spectrometry	Canberra 24% efficient* intrinsic, Ge detector in an Applied Physical Technology 10 cm graded lead cave; Canberra S-100 MCA
Liquid Scintillation (tritium and C-14)	Beckman LS-6000TA Liquid Scintillation Counter
Gross Alpha/Beta (Wet Chemical Analysis for Sr-89 and Sr-90)	Tennelec LB-5100 Alpha/Beta Counting System
Gamma Surveys	Eberline Model FH 40G-10 low range gamma survey meter (range 10 nSv/h to 1 Sv/h for 30 keV to 3 MeV photons).
Thermoluminescent Dosimetry	Panasonic UD-710A Automatic TLD Reader and UD-814A1 ($CaSO_4$) dosimeters

*relative to a 3x3 inch sodium iodide detector

In gamma spectrometry analysis, all significant peaks in the spectrum are identified either by reference to a database library of about 150 radionuclides, or by manual reference to compilations of all known radionuclides. In addition, approximately 20 selected radionuclides are specifically searched for in every sample with the exception of Air Iodine samples in which only I-131 is selected. The selected radionuclides include those that are produced in PLGS, and which would be readily detectable because of their abundance (high fission yield) and high

branching ratios for gamma emissions. Naturally occurring gamma emitters, with the exception of Be-7, K-40 and Ac-228, are not included in this report. These excepted radionuclides are sometimes useful as general indicators of the consistency of the analytical techniques.

The peak search and analysis program SAMPO is used to process spectra. The library of radionuclides uses data of the Oak Ridge Laboratory. There are three categories of radionuclides evaluated:

- selected nuclides of key fission and activation products
- all other identified radionuclides, including natural radionuclides
- detected energy peaks for which no identification can be readily made.

The three categories cover all possible eventualities in a spectral analysis and ensure that no significant radionuclides or photon energies will be overlooked.

The usefulness of gross alpha/beta analysis lies primarily in screening samples (to determine whether more detailed analyses should be performed) and showing trends. The reported alpha and beta values are assessed with respect to Am-241 and Sr-Y-90 calibration sources, respectively.

Wet chemical analysis for Sr-89/90 on Gaseous Effluent Monitoring (GEM) and Liquid Effluent Monitoring (LEM) samples follow the American Society for Testing and Materials procedure (using column chromatography).

Liquid samples, other than milk, are acidified upon receipt to keep radionuclides from plating out on the container walls. Perishable samples are refrigerated or frozen.

B.2 Sample Collection and Analysis

Airborne Particulates

Airborne particulates are collected on a 47 mm diameter Gelman Type A glass fibre filter, through which air is drawn at about 60 L/min (approximately 2400 m^3 for a 28 day continuous sample). The volume of air sampled is measured with an in-line integrating dry gas meter. Every month the filters are replaced and the used ones are returned to the laboratory for analysis. Sampling is therefore continuous throughout the year, the only interruption (other than power failure or pump breakdown) being the few minutes for a filter change.

Air particulate filters are analysed by gamma spectrometry as soon as possible after collection to minimise loss of information through radioactive decay (ensure detection of any short lived gamma emitters that may be present, and to minimize any decay corrections). Samples are counted for 5000 s on the Ge detector.

Approximately three days after the end of the sample collection interval, each filter is counted for 100 minutes for the simultaneous determination of gross alpha and gross beta activities. Counting is

delayed to allow for the decay of the short-lived radon progeny that would otherwise complicate the analysis.

If significant alpha/beta levels are detected (twice the normal level), further investigation is initiated (longer gamma counts or radiostrontium determinations).

If significant levels of Sr-89/Sr-90 (1% of Weekly DEL) are detected in the chemical analysis of Gaseous Effluent Monitor (GEM) filters, then the air monitoring station particulate filters are also to be analysed for these radionuclides.

Airborne Radioiodine

Airborne radioiodine is collected in an activated charcoal cartridge placed downstream of the particulate filter. The cartridges are Nuclear Consulting Services NUSORB® (47 mm diameter and 48 mm length), containing 5% TEDA by weight. For a 28 day continuous sample approximately 2400 m^3 of air is sampled at a flow rate of about 60 L/min. The volume of air sampled is measured with an in-line integrating dry gas meter.

Iodine-131 is the major nuclide of interest on the charcoal cartridges. The cartridges are counted in groups of four for 50 000 s on the gamma spectrometer. Counts are performed as soon as possible after collection because of the relatively short-half life of I-131 (8 days). If radioiodine is detected, then the cartridges are re-analysed individually. Other fission product radioiodines, with much shorter half-lives (minutes to hours), decay before they reach the sample location or during the time the sample is being collected. If a significant release of radioiodine were noted from the station in this interval, the samples would be changed and analysed earlier to minimize errors from decay corrections.

Airborne Tritium

A fraction of the flow in the air monitoring sample station is diverted through a molecular sieve container (Linde type 13X sieve material), to extract water vapour from the sampled air. Sample volume is measured with an in-line integrating dry gas meter.

Sampling is continuous at each location throughout the year, but is interrupted for a few minutes every month to exchange sieve containers. Since the amount of water absorbed by the molecular sieve from a given volume of air depends upon absolute humidity, flow rates are adjusted seasonally (using a Dwyer flow meter) to avoid saturation of the sieve material and to ensure adequate sample collection.

For tritium analysis by liquid scintillation counting, 6 mL of water taken from the molecular sieve condensate is counted for 100 minutes.

Airborne Carbon-14

An aquarium pump bubbles air through 2N NaOH (1 L), into which carbon dioxide from the air is absorbed. Any C-14 as CO_2 is also absorbed.

The volume of air sampled is assessed by gravimetric analysis of the dissolved carbon dioxide precipitated from solution as barium carbonate. For C-14 analysis by liquid scintillation counting, 4 mL of the NaOH solution in 15 mL of Hionic Fluor® is counted for 100 minutes.

Environmental Gamma Radiation (TLD)

The environmental thermoluminescent dosimeter is composed of one element of natural lithium borate with no extra filtration, and three elements of calcium sulphate with lead filtration of about 700 mg/cm^2. The badge is sealed in plastic, placed in a screw cap plastic container and suspended about 1 m above the ground for a period of three months. This will measure the ambient gamma dose, whether it is from activity in the air, from the ground or cosmic in origin.

Readout is by the Panasonic UD-710A Automatic Reader. For typical quarterly measurements in the region of 150-200 μSv, measurements can be made to ±10% at the 95% confidence level.

Soil

Soil samples are collected in undisturbed locations away from nearby buildings or trees. Level areas with some vegetation are preferred. A representative sample (approximately 1.6 kg) of the top 25 mm of a 20 cm by 20 cm area of soil is placed in a disposable polyethylene container.

The soil is dried on a disposable aluminum tray (at 80 °C) and sifted through a 0.5 mm sieve in the laboratory (a 1 mm sieve is used for coarse soils). Approximately 0.25 kg of dry soil is counted by gamma spectrometry for 5000 s.

Food

Garden produce and berries, which are either collected or purchased, require no special preparation. The edible portion is put in a calibrated container and weighed (size varies). This is counted by gamma spectrometry for 5000 s.

Milk

A 4L sample is purchased and placed in a clean polyethylene container.

For gamma spectrometry, a 3.6 L aliquot is measured into a marinelli beaker. The remainder is distilled, and a 6 mL aliquot is analysed by liquid scintillation counting for 100 minutes. Count

times are 50 000 s for gamma spectrometry and 100 min for tritium analysis.

Water

A 4L sample of well water, pond water, lake water or surface runoff is collected in a clean polyethylene container.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectrometry. After gamma analysis, well water samples (125-500 mL, depending upon the dissolved solids content) are evaporated to dryness on stainless steel planchets for gross alpha/beta analysis. For tritium analysis by liquid scintillation techniques, a 6 mL aliquot is analysed by liquid scintillation counting. For gamma spectrometry, the sample is counted for 5000 s. For tritium and gross alpha/beta analyses, samples are counted for 100 min. A level twice the normal level for alpha/beta will initiate further investigation (longer gamma counts and/or Sr-89/90 analyses).

Measurements of gross alpha and beta are made about two weeks after sample collection. This delay avoids analytical interference from radon progeny whose activity is tied to that of the parent, which decays with a half-life of about 3.8 days. Natural radon and radon progeny occur in well waters everywhere and are known to reach high concentrations in many New Brunswick locations.

Vegetation

The only vegetation types routinely collected and analysed are tree lichen (Spanish moss) and various ground mosses such as Cladonia and Lycopodium. They concentrate a wide range of radionuclides, both natural and man-made. This makes them sensitive indicators of radionuclides in the environment even though they are not identified in the pathway to man.

About 25 g or more of each of the samples is collected and air-dried before analysis. No special preparation is required. The sample is placed in a calibrated container and weighed. This is counted by gamma spectrometry for 5000 s.

Precipitation

Rain is collected continuously during the milder months.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectrometry. For tritium analysis by liquid scintillation techniques, a 6 mL sample of water is counted for 100 min. For gamma spectrometry, the sample is counted for 5000 s.

Sediment and Beach Surveys

Beach sediment samples are collected near the low tide mark, with preference being given to the top 10 mm of the fine sediment characteristic of tidal mud flats. A disposable polyethylene container is used to collect about 1 kg of sample. In addition, direct gamma radiation dose rate measurements are made at each sediment site using an Eberline Model FH 40G-10 low range gamma survey meter (range 10 nSv/h to 1 Sv/h for 30 keV to 3 MeV photons). The meter is held for one minute at a point one metre from the inter-tidal surface. After the sediment sample has been collected, this is repeated.

The sample is transferred to a disposable aluminum tray for drying at 80 °C. Dried, caked samples are broken into their original free granular form with a porcelain mortar and pestle, and sieved through a 0.5 mm mesh to collect the fines for analysis (a 1 mm sieve is used for coarse sediments). Approximately 0.25 kg of dried sediment is counted by gamma spectrometry for 5000 s.

Seafood

The inshore fishery throughout the Maritimes has declined since the OERMP was started in 1982. Some of it has been closed to any kind of harvesting. However, species of local seafood are collected when available from local fishermen. Sampling focuses on fish, lobsters and clams. Some of the areas where clam harvesting is prohibited are sampled with the permission of the Department of Fisheries and Ocean. Other seafood species are more mobile and can sometimes be found throughout the area: crab, periwinkle, aquaculture salmon, scallops, herring, mackerel, dogfish, cod, haddock, sea urchin, mussels, and flounder. The severe restrictions placed on the inshore fishery as well as the depletion of stocks make many of these samples unavailable most of the time (sometimes spanning years). However, whenever they are available an effort is made to collect as many samples as possible. Approximately 0.5 kg of fresh seafood is collected per sample.

Approximately 0.25 kg of each sample is prepared for gamma spectrometry. Lobsters are cooked first, and the edible meat is removed for analysis. Clams, periwinkles, and crab are analysed whole, with a yield factor applied to account for the mass of the inedible shell. The edible portion of fish is analysed. Samples are counted for 5000 s.

Aquatic Plants

Dulse (Rhodymenia palmata), an edible seaweed which is commercially harvested in the area, is collected monthly when available. Other species of seaweed concentrate a wide range of radionuclides, both natural and man-made. This makes them sensitive indicators of radionuclides in the environment even though they are not identified in the pathway to man.

A portion of the seaweed or dulse is put in a calibrated container and weighed (size varies). This is counted by gamma spectrometry for 5000 s.

Seawater

A 4L sample is collected in a clean polyethylene container.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectrometry. For tritium analysis by liquid scintillation techniques, a 6 mL sample of water is counted for 100 min. For gamma spectrometry, the sample is counted for 5000 s.

If significant levels of Sr-89/90 (1% of Monthly DEL) are detected in the chemical analysis of the LEM composite, then the seawater is also to be analysed for these radionuclides.

Miscellaneous Samples

This category encompasses all of those samples collected that do not fall within the other categories. It is a mechanism by which the lab can track and evaluate media for potential inclusion in the program. It gives the program flexibility and freedom and encourages the scientific curiosity of lab staff. A few of the media types started out this way. As many as 50 samples per year are analysed, including deer liver, mud puddles, snow, sea urchin and mussels..

Bore Holes

A 4L sample of water is pumped out of the bore hole into a clean polyethylene container.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectrometry. For tritium analysis by liquid scintillation techniques, a 6 mL sample of water is counted for 100 min. For gamma spectrometry, the sample is counted for 5000 s.

Parshall Flume

A 4L sample of water is collected by PLGS staff from the Parshall flume systems.

A portion is removed for tritium analysis, and the remainder is acidified (15 mL of 70% nitric acid per 4 L sample). Of this, 3.6 L is measured into a marinelli beaker for gamma spectrometry. For tritium analysis by liquid scintillation techniques, a 6 mL sample of water is counted for 100 min. For gamma spectrometry, the sample is counted for 5000 s.

Hemlock Knoll Regional Sanitary Landfill

In December 1999, PLGS began disposing of its non-active waste at the public landfill facility. A monitoring program was established prior to the first shipment. It includes sampling of water from the leachate, bore holes and various holding ponds; sampling of the soil and gamma surveys of the disposal cell surface; and dosimeter placement at key locations.

Although some extra precautions are observed due to the potential biohazard of some of these samples, they are analysed according to established procedures previously described.

Appendix C
Location Codes

A 5m	PLGS Dry Fuel Storage Facility -5 m NNE from perimeter fence
A 10m	PLGS Dry Fuel Storage Facility -10 m NNE from perimeter fence
A 15m	PLGS Dry Fuel Storage Facility -15 m NNE from perimeter fence
A 20m	PLGS Dry Fuel Storage Facility -20 m NNE from perimeter fence
A 25m	PLGS Dry Fuel Storage Facility -25 m NNE from perimeter fence
A 50m	PLGS Dry Fuel Storage Facility -50 m NNE from perimeter fence
A 75m	PLGS Dry Fuel Storage Facility -75 m NNE from perimeter fence
A 100m	PLGS Dry Fuel Storage Facility -100 m NNE from perimeter fence
A 118m	PLGS Dry Fuel Storage Facility -118 m NNE from perimeter fence
A01R	Bocabec –Barry & Michelle Schriver
A02R	Bocabec -field across from A01R
A03R	Bocabec -inter-tidal zone
A04	Bayside -Alexander Muir (Fairmile Farm)
A05R	Letete
A06	Digdeguash
A07	Beaver Harbour
A08	Back Bay
A09	Chamcook
A10R	Grand Manan

A11	Oak Bay / Waweig
B 5m	PLGS Dry Fuel Storage Facility -5 m WNW from perimeter fence
B 10m	PLGS Dry Fuel Storage Facility -10 m WNW from perimeter fence
B 15m	PLGS Dry Fuel Storage Facility -15 m WNW from perimeter fence
B 20m	PLGS Dry Fuel Storage Facility -20 m WNW from perimeter fence
B 25m	PLGS Dry Fuel Storage Facility -25 m WNW from perimeter fence
B 50m	PLGS Dry Fuel Storage Facility -50 m WNW from perimeter fence
B 75m	PLGS Dry Fuel Storage Facility -75 m WNW from perimeter fence
B 100m	PLGS Dry Fuel Storage Facility -100 m WNW from perimeter fence
B 150m	PLGS Dry Fuel Storage Facility -150 m WNW from perimeter fence
B 200m	PLGS Dry Fuel Storage Facility -200 m WNW from perimeter fence
B01	New River Beach -inter-tidal zone
B02	Pocologan
B03	New River Beach -park
B04	New River Harbour to Pocologan Harbour
B10	Pennfield
BAXR	Baxter's Dairy
BB	PLGS -Boiler Blow-down
BD	Belledune GS

C01	Lepreau Harbour –inter-tidal zone
C03	Lepreau
CCW	PLGS -Condenser Cooling Water
CH	Chatham GS
D01	Little Lepreau Basin -inter-tidal zone (remnants of clam shack)
D02	Little Lepreau
D03	Little Lepreau –Chester McPherson
D04	Little Lepreau Basin –inter-tidal zone (remnants of boat wreck)
DH	Dalhousie GS
DUMP	PLGS –onsite landfill
DWC	PLGS -drinking water fountains
E01	Maces Bay -Floyd Small
E02	Maces Bay -Fundy Senior Citizens Centre
E03	Maces Bay -inter-tidal zone
E04	Maces Bay Cemetery
E05	Fundy Shores Elementary School -outside
E06	Fundy Shores Elementary School -inside
EPA	US Environmental Protection Agency
F01	Welch Cove -Dave Wright
F02	Welch Cove -inter-tidal zone
G01	Indian Cove -inter-tidal zone

G02	Point Lepreau –lighthouse
G03	offshore -within 2 km of Point Lepreau lighthouse
G04	Point Lepreau -inter-tidal zone south of PLGS condenser cooling water out-fall
GEM	PLGS -Gaseous Effluent Monitor
GL	Grand Lake GS
H01	Duck Cove -duck pond
H02	offshore -close to PLGS condenser cooling water out-fall
H03	Duck Cove -inter-tidal zone
H04	PLGS -across the road from old site of Information Centre building
H05	PLGS -start of nature trail near old site of Information Centre public display trailers
HS	Hanson Stream Reservoir
I00	PLGS Solid Radioactive Waste Management Facility -general site area
I00A	PLGS Solid Radioactive Waste Management Facility -south fence (east side)/Bore Hole A
I00B	PLGS Solid Radioactive Waste Management Facility -south fence (centre) / Bore Hole B
I00C	PLGS Solid Radioactive Waste Management Facility -south fence(west side)/Bore Hole C
I00D	PLGS Solid Radioactive Waste Management Facility -west fence (south side)
I00E	PLGS Solid Radioactive Waste Management Facility -west fence (centre)
I00F	PLGS Solid Radioactive Waste Management Facility -west fence (north side)
I00G	PLGS Solid Radioactive Waste Management Facility -north fence (west side)
I00H	PLGS Solid Radioactive Waste Management Facility -north fence (centre)
I00I	PLGS Solid Radioactive Waste Management Facility -north fence (east side)

I00J	PLGS Solid Radioactive Waste Management Facility -east fence (north side)
I00K	PLGS Solid Radioactive Waste Management Facility -east fence (centre)
I00L	PLGS Solid Radioactive Waste Management Facility -east fence (south side)
I01	PLGS Solid Radioactive Waste Management Facility
I02	PLGS Dry Fuel Storage Facility
I03	PLGS Dry Fuel Storage Facility -general site area
I03A	PLGS Dry Fuel Storage Facility –south side(next to south corner)/well #4(shallow)
I03B	PLGS Dry Fuel Storage Facility –south side (next to west corner) / well #4 (deep)
I03C	PLGS Dry Fuel Storage Facility -west corner / well #7 (shallow)
I03D	PLGS Dry Fuel Storage Facility -west side (next to west corner) / well #7 (deep)
I03E	PLGS Dry Fuel Storage Facility -west side (next to north corner) / well #6 (shallow)
I03F	PLGS Dry Fuel Storage Facility -north corner / well #6 (deep)
I03G	PLGS Dry Fuel Storage Facility –north side(next to north corner)/well #5(shallow)
I03H	PLGS Dry Fuel Storage Facility –north side (next to east corner) / well #5 (deep)
I03I	PLGS Dry Fuel Storage Facility –east corner / well #2 (shallow)
I03J	PLGS Dry Fuel Storage Facility –east side (next to east corner) / well #2 (deep)
I03K	PLGS Dry Fuel Storage Facility -east side (next to south corner) / well #3 (shallow)
I03L	PLGS Dry Fuel Storage Facility -south corner / well #3 (deep)
I03M	PLGS Dry Fuel Storage Facility -well #1 (shallow)
I03N	PLGS Dry Fuel Storage Facility -well #1 (deep)
I11	PLGS -woods between plant & Solid Radioactive Waste Management Facility
I75	PLGS -85 m from stack in the direction of north 73° east (on pole)
I86	PLGS -2nd pole from SRWMF driveway when heading north on main plant road
I87	PLGS -3rd pole from SRWMF driveway when heading north on main plant road
I88	PLGS -4th pole from SRWMF driveway when heading north on main plant road
I89	PLGS -5th pole from SRWMF driveway when heading north on main plant road
I90	at distribution line on west side of dirt road connecting Rte.790 to Duck Cove
I91	100m north of distribution line on west side of dirt road connecting Rt790 to Duck Cove
I92	200m north of distribution line on west side of dirt road connecting Rt790 to Duck Cove
I93	300m north of distribution line on west side of dirt road connecting Rt790 to Duck Cove
I94	400m north of distribution line on west side of dirt road connecting Rt790 to Duck Cove
I95	500m north of distribution line on west side of dirt road connecting Rt790 to Duck Cove
I96	on the old Dupont warning sign at the end of the old "dynamite road"
I97	on the west side of the clearing at the end of the old "dynamite road"
I98	PLGS -north of Dry Fuel Storage Facility (200 m north of transmission line)
I99	PLGS -north of Dry Fuel Storage Facility - 100 m north of transmission line
J00	PLGS -180 m from stack in the direction of south (on fence)
J20	PLGS -115 m from stack in the direction of south 19° east (on fence)
J35	PLGS -135 m from stack in the direction of south 34° east (on sign)
J70	PLGS -70 m from stack in the direction of south 69° east (on pole)
K01	PLGS -95 m west of south gate leading to the lighthouse
K02	PLGS Condenser Cooling Water Pump-house -east fence near surge shaft

K03C	PLGS sewage lagoon (chlorine contact tank)
K03E	PLGS inactive drainage (east lagoon)
K03W	PLGS inactive drainage (west lagoon)
L01	PLGS - site of old cement plant
L02	PLGS –switchyard
L03	PLGS -outer security building (main gate)
L04	PLGS –construction stores
LAB	Fredericton –Health Physics Environmental Laboratory
LEM	PLGS -Liquid Effluent Monitor
M02	PLGS –Administration Building (2nd floor)
MQ	Mactaquac GS
N01	Dipper Harbour –Greg Thompson
N02	Dipper Harbour –Dewey Janes
N03	Dipper Harbour –Ethel Thompson
N04	Dipper Harbour –inter-tidal zone
N05	Dipper Harbour –beach behind restaurant
N06	Dipper Harbour –offshore
P01	Chance Harbour
P02	Little Dipper Harbour
P03	Liberty Hill
P04	Round Meadow Farm

P05	Chance Harbour -2 km offshore
PLGS	PLGS -general
Q01R	Lorneville
S00	Saint John and surrounding area
SPL	Spruce Lake reservoir
TAYR	Taymouth
X03R	Fredericton -Chestnut Complex lab
X04R	Fredericton -reference seafood
X05R	Fredericton -reference milk test (B. Gay)
X10	Fredericton Junction –Atlantic Dairy Institute
Y######	Hemlock Knoll Regional Sanitary Landfill

Appendix D
Abbreviations

- ***AECB*** Atomic Energy Control Board
- ***AECL*** Atomic Energy of Canada Limited
- ***CL*** Critical Level
- ***CSA*** Canadian Standards Association
- ***CCW*** Condenser Cooling Water
- ***DEL*** Derived Emission Limit
- ***GEM*** Gaseous Effluent Monitor
- ***LEM*** Liquid Effluent Monitor
- ***LLD*** Lower Limit of Detection
- ***NIST*** National Institute of Standards and Technology
- ***OERMP*** Operational Environmental Radiation Monitoring Program
- ***PLGS*** Point Lepreau Generating Station
- ***SRWMF*** Solid Radioactive Waste Management Facility
- ***QA*** Quality Assurance
- ***QC*** Quality Control
- ***TLD*** Thermoluminescent Dosimeter
- ***USEPA*** United States Environmental Protection Agency

Appendix E
Environmental Reports Of Previous Years

PRE-OPERATIONAL (1976 - 1981)

1 Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station. October 1, 1976 to June 30, 1979. NBEPC-HP-79-1. J.A. Flanigan and J.J. Paciga. Sept. 1979.

2 Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station. January 1, 1979 to December 31, 1979. NBEPC-HP-80-1. J.A. Flanigan. Sept. 1980.

3 Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station. January 1, 1980 to December 31, 1980. NBEPC-HP-81-1. J.K. Sutherland and J.A. Flanigan. July 1981.

4 Pre-Operational Environmental Radiation Monitoring Data for Point Lepreau Generating Station. January 1, 1981 to December 31, 1981. NBEPC-HP-82-1. J.K. Sutherland. February 1982.

OPERATIONAL (1982 - 1996)

5 Operational Environmental Radiation Monitoring Program. Revision 1, January 1982. RD-01364-L15. J.K. Sutherland. Revision 2, June 1983. Revision 3, September 1985. Revision 4, February 1989. Revision 5, August 1993. Revision 6, September 1997.

6 Environmental Radiation Monitoring Data for Point Lepreau Generating Station. January 01, 1982 (to 1997) to December 31, 1982 (to 1997). HP-07000-83(to 98)-1. J.K. Sutherland. March 1983 (to 1998).

7 Environmental Radiation Monitoring Data for Point Lepreau Generating Station. January 01, 1998 to December 31, 1998. HP-07000-99-1. J.C. McCulley. April 1999.

Appendix F
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9. Sutherland, J., *External Beta/Gamma Dosimetry Program, HP-03541-2-TL Rev. 3,* Point Lepreau Generating Station Procedure Document, 1995.

10. McCulley, J., *Environmental Radiation Monitoring Program Procedures, HP-03541-2-EN,* Point Lepreau Generating Station Procedure Document, work in progress.

11. NBS Special Publication 456, *Measurements for the Safe Use of Radiation,* US Department of Commerce, 1976.

Appendix G
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